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Color Television Signal
Eidophor System
Fischer System—A Reprint
Dichroic Mirrors
Television Recording—Abstract
Synchro-Lite Projector
Television Projector
Welding Arc Photography
Photography of Underground Explosions
American Standard

THIS ISSUE IN TWO PARTS
Part I, April 1953 Journal
Part II, Symposium on Magnetic Striping of Film

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Recommendations of the National Television System Committee for a Color Television Signal

By A. V. LOUGHREN

I. INTRODUCTION

The work of the National Television System Committee on color television has probably constituted a fundamental and major advance. This report of the NTSC's accomplishments is the author's view, and not an official statement on behalf of that Committee.

To assist in the understanding of the significance of the several elements in the total contribution, a review of some of television's history is useful.

In 1949 the Federal Communications Commission issued a Notice of Proposed Rule Making[1] dealing with color television, and held a hearing on the subject which lasted many months. The Commission appears to have had two purposes in this course of action. First, it certainly wanted to bring about a color-television service to the public at an early date. Second, and perhaps from its point of view, equally important, it wanted to establish whether or not color television would require different treatment in frequency allocation than did monochrome television. It had become apparent before the issue of the notice that the 12 channels then available for television were insufficient to satisfy the Commission's objective of a nationwide and competitive television broadcast service. Additional channels in excess of 50 were going to be required. An uncommitted portion of spectrum known to be reasonably suitable for television broadcasting lay below 1000 mc, sufficient in extent for 70 added channels if 6 mc was sufficient channel width. No other frequency space gave promise of being available within the foreseeable future for television broadcasting. This state of affairs is shown in Fig. 1. The Commission was faced, therefore, with the difficulty "If color television cannot be done in a 6-mc channel, we must either have less channels than needed for a nationwide competitive service or we must postpone color television into the indefinite future"; and there had been evidence, in 1947, that color-television broadcasting of quality comparable to monochrome television would require 12- to 15-mc channels.

The Commission concluded, from the evidence presented in the hearing, that color television could be broadcast in a 6-mc channel, that the field-sequential method of color-television broadcasting was the only method which at that time had been demonstrated both to give pic-

Presented on October 6, 1952, at the Society's Convention at Washington, D.C., by A. V. Loughren, Hazeltine Corp., Little Neck, L.I., N.Y. The author has reviewed the entire Convention transcript and brought salient points from the oral discussion into this presentation, brought up to date for the *Journal*.

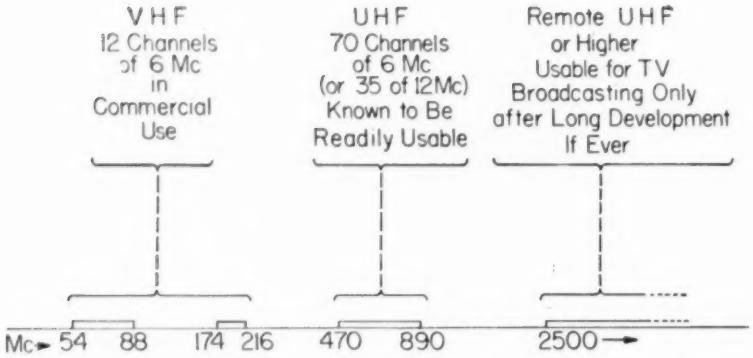
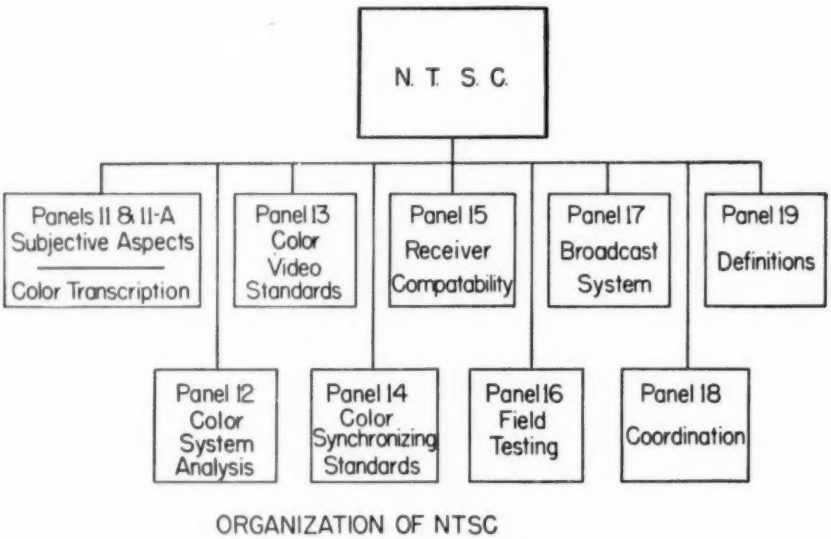


Fig. 1. Existing and potential television allocations, as of 1949; immediate need, 70 or more channels.



ORGANIZATION OF NTSC

Fig. 2. Organization of National Television System Committee.

tures with some prospect of viewer acceptance and to be practicable with apparatus then readily available, and the Commission adopted that method.[2,3]

In response to the Commission's notice of the hearing a large number of interested parties in the television broadcasting and television apparatus manufacturing industries established a National Television System Committee to provide a means for the industry to assist the Federal Communications Commission by making information available to it in the course of the hearing. Before, during, and following the hearing, some of the members of this committee had made substantial progress with both the theoretical and practical aspects of

a method of color-television broadcasting quite different from the field-sequential method. In the fall of 1950 the NTSC set up a six-member Ad Hoc Committee to investigate the progress of these developments and to report back a recommendation as to whether or not NTSC should work actively toward the completion and experimental verification of a color-television signal based on all of these developments. In the spring of 1951 the Ad Hoc Committee turned in its report. The committee found that the developments had indeed reached the point where it seemed highly likely that further work would lead to a most advantageous form of color-television broadcast signal. The committee's report recommended that the NTSC proceed actively to study the signal, to arrange for such tests as were necessary to select the signal characteristics, and to pursue a program of field tests of such scope as to show clearly beyond any doubt whether or not the signal resulting from these choices was in fact possessed of the advantages claimed for it. The National Television System Committee approved the report of its Ad Hoc Committee and it proceeded in accordance with that report to establish additional panels organized specifically for the several tasks involved, as presented in Fig. 2. Panels 13 and 14 are responsible for establishing the signal specifications, Panels 15, 16 and 17, for the independent testing of the recommendations of the first-named two panels, and the remaining panels provide for important functions auxiliary to those already described. In the ensuing months the signal specification has been established, been subjected to extensive studies in both laboratory and field, and has been modified to make certain minor improvements. The committee's work is now at the point where the final field tests are expected to start in the immediate future.

II. THE BASIC PRINCIPLES

Out of the work in this field certain principles have emerged which appear to be basic to a system of color-television broadcasting if that system is to show full utilization of the portion of the frequency spectrum allocated to it. Among these principles are the following:

1. The electrical quantities in the signal shall represent the transmitted color in terms of its luminance, dominant wavelength and purity; alternatively, these may be thought of as brightness, hue and saturation.

2. The spectrum space occupied by the luminance information must be shared by the color information without adversely affecting the transmission of either.

3. The color-television signal must provide satisfactory black-and-white pictures on the present monochrome sets if color broadcasting is to grow rapidly into an important public service.

These principles are worth examination in some detail.

The Electrical Description of Color

There are many ways of including in an electrical signal three quantities which when taken together can be used to represent a color. Only two of these need concern us here. In the first of these, separate elements of the signal are used to represent the respective intensities of three primary colors — for example, red, green and blue — which taken together will produce a resultant color which to the eye is a match for the original color. This method of electrically describing a color appears to be simple and straightforward, and it can be shown to have the further advantage that the three indications may be pre-

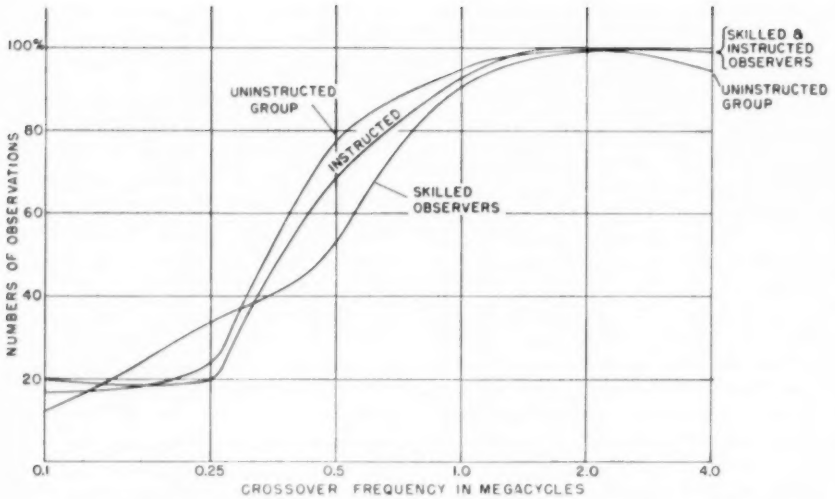


Fig. 3. Comparison of "Satisfactory Picture" curves for various skills.
Courtesy, *Proc. I.R.E.* (Ref. 6, Fig. 7).

sented successively rather than simultaneously without altering too greatly the visual result, at least over a limited range of conditions. It is therefore possible by fairly easy modifications of a black-and-white television system to arrange for the display of one field of the picture in each of the primary colors successively. Theoretical and experimental studies of such a system appear to have established the following system properties:

1. If the color-television system is to exhibit essentially the same resolution as that of a typical monochrome system, it must present as much information for each of the three primary colors as the monochrome system presents; it must therefore transmit three times as much total information and use three times as much bandwidth.

2. If the color system confines itself to the same bandwidth as the monochrome system, it must as a practical matter exhibit decreased resolution and must also operate with different scanning standards than the monochrome system.

Considering now the electrical description of color in terms of brightness, hue and saturation, we note first that these quantities must be presented simultaneously; there is no mechanism in the eye which permits these quantities to be accepted successively in the fashion that persistence of vision permits red, green and blue intensities to be accepted successively. Next we find that the visual acuity for the brightness component of color, that is, the ability to perceive fine detail, is exactly the same as that for the brightness component of a monochrome image, but visual acuity for changes of color unaccompanied by changes of brightness is very much poorer than the eye's acuity for brightness detail; this indicates that the amount of information which must be transmitted to add color to a black-and-white picture is very much smaller than the amount of information required to produce a satisfactory black-and-white picture in the first place, if the color is added by informa-

tion which describes hue and saturation.[4,5]

Panel 11 of the NTSC conducted a careful set of experiments,[6] the results of which are summarized in Fig. 3. In making these tests all pictures were presented with a bandwidth for the luminance component extending out to 4 mc. The additional information required to insert color into the picture may be thought of as "color-difference" signals; two color-difference signals taken together can be used to tell how far from gray and in what direction from gray a particular color is, relative to a gray of exactly the same luminance. If the color-difference signals have a narrower bandwidth than the luminance signal, then color gradations are not as sharp on the picture although the full sharpness of luminance gradations is preserved. The horizontal coordinate (on the chart, called "crossover frequency," in reference to the specific apparatus of the test) is the amount of bandwidth devoted to each of the two color-difference signals in a particular observation. The vertical coordinate refers to the percentage of the number of observations in which the various classes of observers rated the picture quality as "satisfactory." The curves indicate that even with a luminance bandwidth of 4 mc, and the observers permitted to sit where they wished, there was no significant improvement in pictorial quality obtained by increasing the bandwidth devoted to color-difference signals above 1 mc. The curves also show that this statement is true both for skilled and for lay observers.

In the tests made by Panel 11 both color-difference signals had the same magnitude in any one observation. Subsequent tests, the results of which have not yet been published, have indicated that along a particular direction of color difference the bandwidth may be decreased to approximately $\frac{1}{2}$ mc without noticeable impairment of the picture, especially if the bandwidth in another direction is retained at the value of 1 mc or perhaps slightly greater.

We also note that the eye responds only slowly to changes in color; thus small rapid fluctuations about a correct color value go unperceived, whereas corresponding fluctuations about the correct brightness value would be perceived immediately as flicker. This latter point indicates that greater exposure to electrical disturbance may be permitted the color component of the signal without impairment of performance than may safely be permitted to the monochrome component of the signal.

Sharing of the Channel

The luminance component of a color-television signal has the task of controling, element by element, the brightness of the received image. It is most important for successful color-television transmission that this task be well discharged. The standards of the Federal Communications Commission for monochrome television provide the means for discharging this task well, and the use of these standards should certainly be examined as a basis for a successful color-television system.

It has been known for a long time that a normal monochrome television signal by no means completely fills its channel;[7,8] the spectrum consists in general of a component at each harmonic of the line-scanning frequency, with each such component being accompanied by a cluster of smaller components spaced from the main component by the field-scanning frequency. Figure 4 illustrates a small section of the spectrum, showing the region in the vicinity of the eighty-second and eighty-third harmonics of the line-scanning frequency. The dotted line half-way between the groups illustrates the absence of any signal information at this region. The signal spectrum consists therefore of groups of components at the successive harmonics of the scanning-line frequency, or bet-

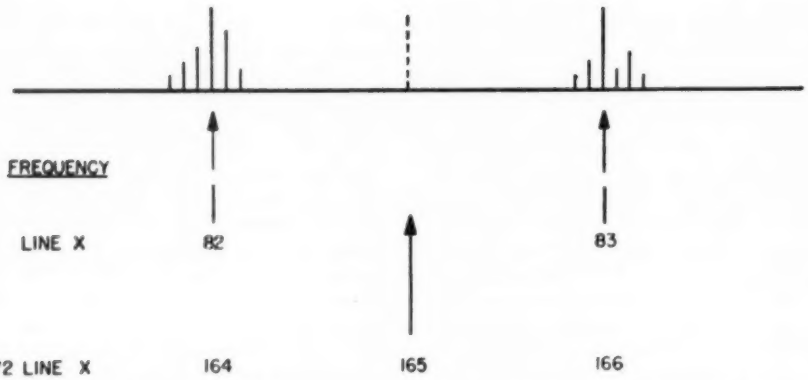


Fig. 4. Small section of the spectrum, region in the vicinity of the 82nd and 83rd harmonics of the line scanning frequency.

Courtesy, *Electronics* (Ref. 9, Fig. 1).

ter, at the even harmonics of one-half the scanning-line frequency, and gaps corresponding to the odd harmonics of one-half the scanning-line frequency. We see, therefore, that a second television picture could be transmitted within the same spectrum occupied by our luminance picture if its signal components could be so transformed as to lie at odd harmonics of the scanning-line frequency.

It is also found that even if components are artificially injected into the signal spectrum in positions corresponding to the dotted line of Fig. 4, a normal television receiver will not reproduce these components. The diagram of Fig. 5 illustrates the reasons for this. In the upper line of the figure a signal is shown at the third harmonic of the line-scanning frequency and therefore at the sixth, an even harmonic of half the line frequency. Three full cycles of this signal appear in traversing a single scanning line, and the next scanning line shows three full cycles again. The section at the right of the figure is labeled "Line 3" or "526," and of course line 526 is the first line of the next picture, and therefore lies exactly on top of line 1 one-thirtieth of a second later. The second horizontal line in the diagram shows how line 1 and line 526 add directly to produce an augmented result. In the lower half of the diagram a signal is shown at the third harmonic of one-half the line frequency. This odd harmonic signal repeats in line 3 and also in line 526 exactly opposite in polarity to the position which it took in line 1. The lowest section of the diagram at the right shows that when line 1 and line 526 are superposed, the brighter than average regions in line 1 land on darker than average regions in line 526, and vice versa, and therefore the total contribution to brightness tends to be the same all along the line; the component is therefore not effectively reproduced. If the reproducing device is linear, and if the eye remembers fully for two picture intervals, then this cancellation is exact and complete; in the practical case neither of these requirements is fully met, and so the cancellation is theoretically incomplete but of great practical value.[9]

It is worth emphasizing that we have thus established the fact that a good monochrome television signal, suitable for use additionally as the luminance component of a color signal, has gaps in it in which additional information may be transmitted without affecting

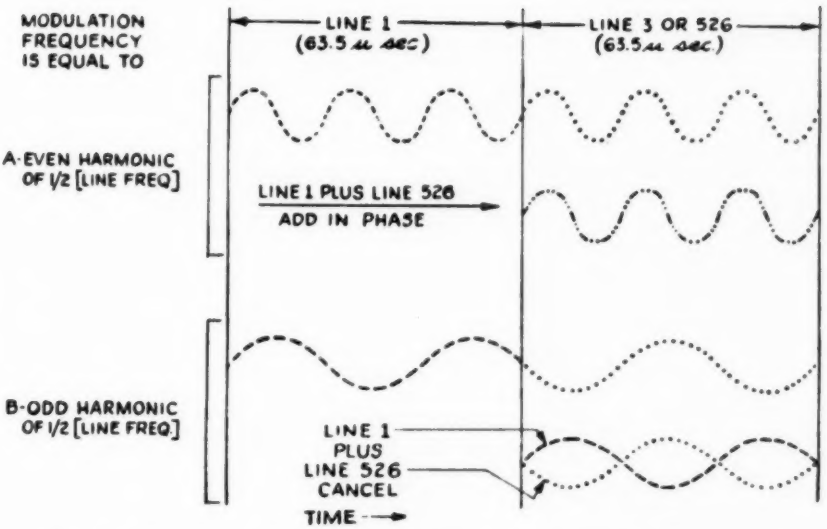

MODULATION FREQUENCY IS EQUAL TO
LINE 1 (63.5 μ sec)
LINE 3 OR 526 (63.5 μ sec)
A-EVEN HARMONIC OF 1/2 [LINE FREQ]
LINE 1 PLUS LINE 526 ADD IN PHASE
B-ODD HARMONIC OF 1/2 [LINE FREQ]
LINE 1 PLUS LINE 526 CANCEL
TIME

Fig. 5. Principle of interference cancellation by frequency interleaving.
Courtesy, *Electronics* (Ref. 9, Fig. 2).

the use of that signal as a luminance signal either for color or for monochrome receivers.

Compatibility Considerations

We have seen that the signal for monochrome television and the luminance component of a color-television signal must satisfy the same set of requirements; we have also seen that idle intervals exist in the transmitted band of this signal in which another signal may be placed, and we shall presently find that the color components of the color-television signal may be placed there; we have also seen that a signal placed in these idle intervals is essentially invisible on a black-and-white receiver. There is no disadvantage then in adopting for the luminance component of a color-television transmission identically the same standards which have been found suitable for a high-grade monochrome transmission. And we should bear in mind that the performance *capabilities* of the black-and-white television signal represented by the FCC's standards, are likely to equal or exceed any demand for performance to be encountered in the foreseeable future.

But there is more to this than the mere absence of a disadvantage. If our color-television signal consists of a luminance component conforming exactly to the present monochrome standards and an interleaved color component which is essentially invisible on monochrome receivers, then our color-television broadcast is also an acceptable black-and-white broadcast, and the potential audience for any such broadcast includes not merely those who have at the time of the broadcast equipped themselves with color-television receivers, but also all viewers equipped with black-and-white receivers. A signal for color television which bears this relation to an existing signal for monochrome television, is said to be compatible with the monochrome signal; the importance of compatibility in bringing about early and widespread adoption of color television, once the

color standards have been accepted and established by the Federal Communications Commission, is thus seen to be extremely great. With compatibility, color television can be given a flying start by its parent, monochrome television; without compatibility, color television must start from a complete standstill; it must face the terrible economic difficulty represented by the situation "too few viewers, therefore very little sponsor money, therefore poor programs, therefore too few viewers."

Important though compatibility is to the rapid introduction of color television, it is perhaps not important enough to justify of itself the adoption of a color-television system markedly inferior to a system which could be developed disregarding compatibility. We should note however that we are not faced with this question; instead, we have the situation in which the basic technical considerations important in the design of a color-television signal coincide with those controlling the design of a monochrome signal, and in satisfying these considerations we find compatibility as an automatic by-product.

III. GENERATION OF THE SIGNAL

A block diagram of the essential elements of the transmitting apparatus is shown in Fig. 6. A camera at the left generates three signals which collectively represent the luminance, hue and saturation of the scene, element by element; in the example shown the actual camera outputs correspond to the red, green and blue components. Gamma correction — to improve the signal-to-noise ratio and incidentally to match approximately the receiver picture-tube curvature — may be introduced at this point.

The resulting signals are electrically added, in the proportions of their respective luminances, to form the monochrome or luminance signal. Normal adjustment for the system is such as to make the three signals from the camera equal if the color represented is that corresponding to standard Illuminant C; under this condition the luminance signal E_Y' is also equal to the gamma corrected voltages E_G', E_R' and E_B'.*

The negative of the luminance signal is developed by the phase inverter; in the two adders shown below it, this signal is added to the red and the blue color signals, respectively, thus forming in the adder the two color-difference signals corresponding to these two primaries. Examining the red color-difference signal in some detail, it is noted that this signal was generated by addition and subtraction of the signals originally produced by the camera. These signals, of course, have their components at even harmonics of one-half the line frequency like the components shown solid in Fig. 4; of course, addition and subtraction of such components does not change their frequency into the positions of the low-visibility, odd-harmonic components, and yet we want these components to be translated into odd-harmonic components so that they may be interleaved between the components of the luminance signal for transmission. If we generate a subcarrier frequency at such a frequency value as, for example, the 455th harmonic of one-half the line frequency, it will be a low-visibility signal, like the dotted line in Fig. 4. If we then use our red color-difference signal to modulate this subcarrier, the sidebands which appear with the subcarrier as a consequence of the modulation process, will be separated from the subcarrier frequency by the same interval that separates the original sidebands from zero frequency; in other words, all of

* See the Appendix for definitions of symbols and formulas not explained in the text and illustrations.

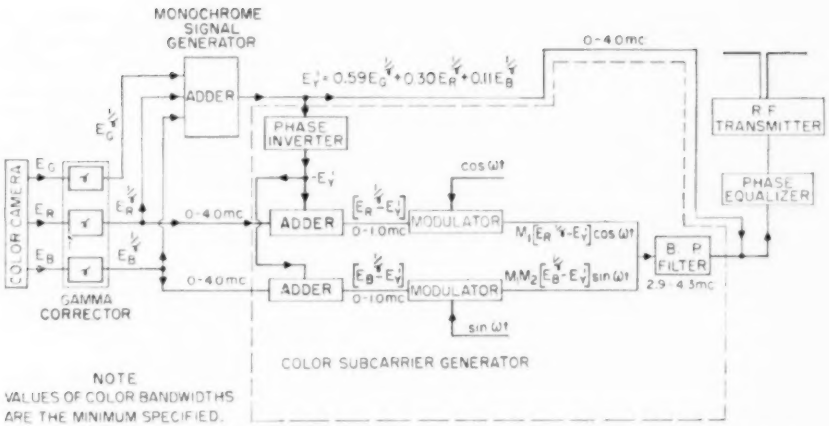


Fig. 6. Block diagram of the essential elements of the transmitting apparatus.
Courtesy, *Electronics* (Ref. 9, Fig. 5).

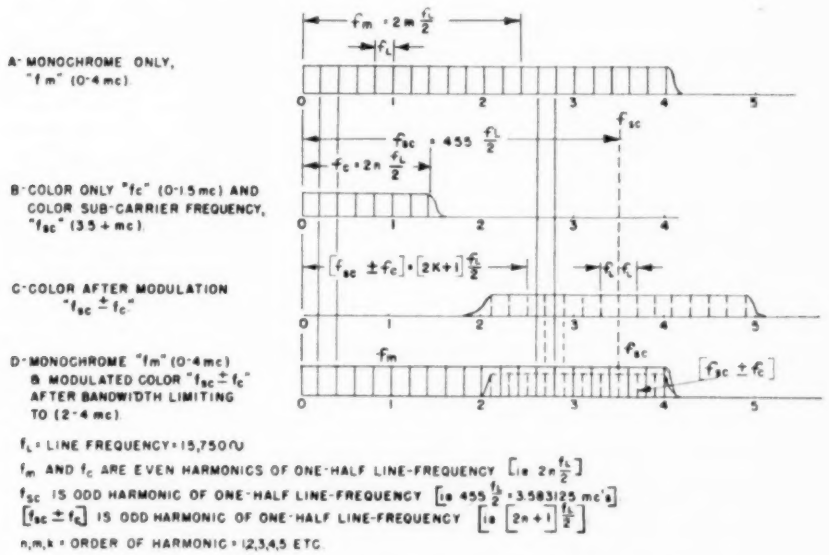

A-MONOCHROME ONLY, "fm" (0-4mc)
B-COLOR ONLY "fc" (0-1.5mc) AND COLOR SUB-CARRIER FREQUENCY, "fsc" (3.5+mc)
C-COLOR AFTER MODULATION "fsc ± fc"
D-MONOCHROME "fm" (0-4mc) & MODULATED COLOR "fsc ± fc" AFTER BANDWIDTH LIMITING TO (2-4mc)
fL = LINE FREQUENCY = 15,750 ∿
fm AND fc ARE EVEN HARMONICS OF ONE-HALF LINE-FREQUENCY
fsc IS ODD HARMONIC OF ONE-HALF LINE-FREQUENCY
[fsc ± fc] IS ODD HARMONIC OF ONE-HALF LINE-FREQUENCY
n,m,k = ORDER OF HARMONIC = 1,2,3,4,5 ETC

Fig. 7. Band-sharing by monochrome and color signals.

the components of the red color-difference signal which were generated as even harmonics of one-half the line frequency, will appear as sidebands of the subcarrier at odd harmonics of one-half the line frequency, and will therefore exhibit low visibility if they are applied to any normal television reproducing system. This frequency transformation is illustrated in Fig. 7. Row A shows the luminance signal and its components in solid lines to represent their being

even harmonics of one-half the line frequency. Row B shows a color-difference signal as generated, again with solidly drawn components representing even harmonics of one-half the line frequency. Row C shows this same signal appearing as modulation on a subcarrier f_{sc}. The spacings of the components are still the same but the subcarrier itself being an odd harmonic, all of the other components must themselves be odd harmonics also. Finally, Row D of the drawings shows the solid lines of the first section and the dotted lines of the third section interleaved as they are in a normal transmission.

Some other characteristics of the signal may be noted by further reference to Figure 6. For example, since the red signal and the signal E_Y' are equal on white, the output of the adder in the red channel, the red color-difference signal, must equal zero on white. It will have an amplitude which we may call positive when the scene is red and an amplitude which we may call negative when the scene is the complement of red, or cyan. Now, if the modulator of Fig. 6 is a balanced modulator, it can be arranged so that its output will also vanish on white; it is advantageous to design the system in this fashion, since this reduces still further the residual perceptibility of the low-visibility components represented by the dotted lines of Figs. 4 and 7, especially in picture highlights which are generally white or relatively unsaturated color. We find, however, that a transmission whose output vanishes when the modulating signal vanishes, is a transmission in which the carrier frequency has been suppressed, leaving only the modulation sidebands. For correct detection of such a transmission the carrier must be resupplied at the detector of the receiver, and we shall provide a synchronizing pulse in the transmission to enable receivers to generate a suitable carrier. The resupplying of a properly synchronized carrier in the receiver offers us another advantage: it permits us to distinguish successfully between phase modulation and amplitude modulation of a single subcarrier; alternatively, we may say that it permits us to modulate two subcarriers at the same frequency 90° apart in phase and transmit their sidebands over the same circuit and yet distinguish each set of sidebands from the other in the receiver. It will be seen that we make use of exactly this property to permit the transmission of the blue color-difference signal as modulation sidebands on the very same subcarrier frequency as the red color-difference signal, with the two subcarriers differing merely by 90° in phase at the subcarrier frequency.

Finally, the two sets of subcarrier sidebands representing respectively red color-difference information and blue color-difference information, are combined and are then added to the luminance signal as illustrated frequency-wise in Fig. 7. The resulting signal is then applied to the transmitter. Let us note again that this signal is in all respects a perfectly normal monochrome television signal to which there has been added, in a fashion which makes it essentially invisible on normal monochrome receivers, the color-difference information which can be used in a color television receiver to reconstruct the original image in full color.

The transmission of two independent sets of modulation sidebands based on the same subcarrier frequency over the same circuit requires that the transmission be on a double sideband basis if the two sets of modulation components are to be separated at the receiver. Consequently, the maximum frequency which we may choose for the subcarrier is a frequency enough lower than the top frequency of the expected passband of the system to satisfy this requirement for double sideband transmission. Now, if one of the modulation components has a bandwidth of a half megacycle, while the other had a bandwidth of a megacycle or greater, the necessity for double

sideband transmission extends out only a half megacycle away from the nominal frequency of the subcarrier; this fact, together with the practical requirements of receiver construction, dictates a subcarrier frequency in the vicinity of 3.5 mc. The exact value of the subcarrier frequency must be, of course, an odd harmonic of one-half the line-scanning frequency; there is an additional minor advantage to be gained by making the difference between the subcarrier frequency and the frequency at which sound is transmitted be also an odd multiple of one-half the line-scanning frequency. The choice of a subcarrier frequency of 3.579545 mc satisfies these requirements without involving any change in the separation between picture and sound carriers as currently specified: a decrease in line-scanning frequency of 0.1% from the presently specified value results from this choice but this decrease is negligible compared to the tolerance presently permitted to the line-scanning frequency itself.

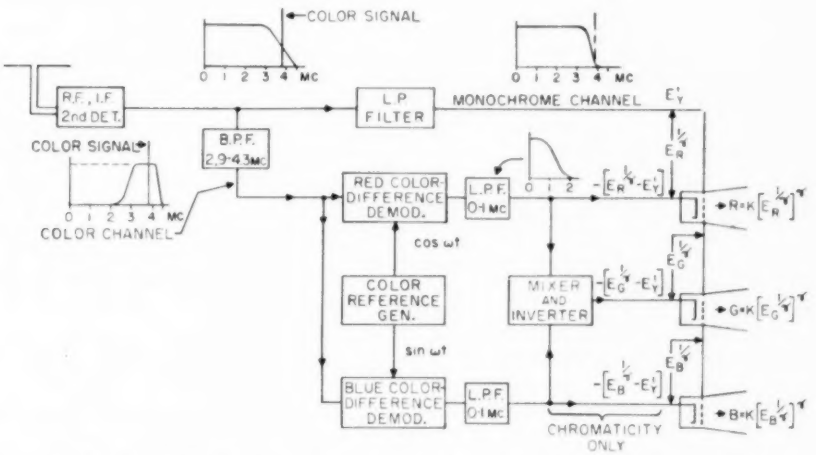


Fig. 8. Elements of one form of receiver for the proposed NTSC signal.

Courtesy, *Electronics* (Ref. 9, Fig. 7).

IV. THE COLOR RECEIVER

Color-television receivers are not the direct concern of the NTSC; the Committee's primary objective is the specifying of a signal for color-television broadcasting which is believed to be a sound basis for the founding of a nationwide color-television service, and the recommending of that signal to the Federal Communications Commission after adequate testing. (Receivers are of interest to the Committee indirectly, however, for two important reasons: first, it is essential that the color-television signal which the Committee recommends be suitable for use with receivers which can be built practically and sold commercially at prices which will interest the public; second, the verifying of the suitability of the Committee's proposed signal is an experimental process and must use both physical transmitters and physical receivers for that verification. A detailed discussion of receivers would therefore be inappropriate in this report of the work of the NTSC. A few words

about the general scheme of receivers for use with the NTSC signal may, however, be appropriate.

Figure 8 shows the elements of one form of receiver for the proposed NTSC signal. In this receiver a three-gun picture tube has been used; other forms of display device are entirely possible.[10] The receiver includes all of the usual elements of a monochrome television receiver such as radio and intermediate frequency circuits, detector, video frequency circuits to feed the picture tube grid, and the usual scanning and high voltage supply circuits for the picture tube. The color circuits are energized from a tap off the main video circuit of the receiver through a filter which passes only the portion of the video spectrum containing the color components. This selected signal includes the modulation sidebands which were generated in the transmitter by application of the original color difference signals as modulation to the color subcarrier; it also includes the components of the luminance signal which appear in the selected frequency band. The luminance components are, of course, even harmonics of half the line frequency while the color sidebands are odd harmonics. A local oscillator in the receiver reproduces the subcarrier frequency which was suppressed at the transmitter; it is kept accurately in phase by reference to the periodic "burst" of the color subcarrier frequency which is transmitted during the synchronizing interval. The local oscillator signal and the color signal selected from the receiver output are both applied to the red color-difference demodulator; its output contains the beat between these, and it is found that one component of that complex beat is the original video-frequency, color-difference signal. The frequency conversion occurring in the production of this beat signal has transformed all of the color modulation sidebands which were odd harmonics of one-half the line frequency as transmitted into even harmonics as the signal appears in the output of the demodulator. These even harmonics are, of course, suitable for producing a visible image on the cathode-ray tube and we therefore apply them to the red gun of that tube. Similar procedure is followed with respect to the blue color-difference signal and the blue gun, the only difference being that the phase of the locally generated subcarrier as applied to the blue demodulator is 90° away from the phase in which that signal is applied to the red demodulator. The green color-difference signal is obtained by a proper addition of the red and blue signals, giving due regard to the algebraic signs of the signals and the required output; alternatively, it may be obtained by the use of a third demodulator if the phase of the local subcarrier applied to that demodulator is properly chosen.

V. CONCLUSION

In its work on color television the National Television System Committee has now formulated a proposal for a color-television broadcasting signal.* The design of the signal is based upon careful study of the information need of the human viewer, and it is believed that the signal is capable of adequately satisfying that need. The signal is transmitted in the same 6-mc channel as our present signals and has the incidental but important feature of being compatible with present monochrome television signals. Transmitting, networking, and receiving apparatus suitable for use with the signal is now becoming available in sufficient quantity to permit thorough field testing of the proposal. It is my expectation that the field test will show conclusively the suitability of the signal for color-television broadcasting.

* See the Appendix.

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APPENDIX: Revised Specifications for Field Test of NTSC Compatible Color Television

Test Specifications—Group I

1. The image is scanned at uniform velocities from left to right and from top to bottom with 525 lines/frame and nominally 60 fields/sec, interlaced 2-to-1.

2. The aspect ratio of the image is 4 units horizontally and 3 units vertically.

3. The blanking level is fixed at 75% (±2.5%) of the peak amplitude of the carrier envelope. The maximum white (luminance) level is not more than 15% nor less than 10% of the peak carrier amplitude.

4. The horizontal and vertical synchronizing pulses are those specified in Sec. 3.682 of Subpart E of Part 3 of the FCC Rules Governing Radio Broadcast Services (as amended April 11, 1952; effective June 2, 1952), modified to provide the color synchronizing signal described in Specif. 21 (Group II of these specifications).

5. An increase in initial light intensity corresponds to a decrease in the amplitude of the carrier envelope (negative modulation).

6. The television channel occupies a total width of 6 mc. Vestigial-sideband

NOTE: These revised specifications were formally released on Feb. 4, 1953, by W. R. G. Baker, Chairman of NTSC, c/o General Electric Co., Electronics Park, Syracuse, N.Y., with the advice that a comprehensive field test would soon be inaugurated. Dr. Baker will welcome comments.

amplitude-modulation transmission is used for the picture signal in accordance with the FCC Rules cited in Specif. 4, above.

7. The sound transmission is by frequency modulation, with maximum deviation ±25 kc, and with pre-emphasis in accordance with a 75-μsec time constant. The frequency of the unmodulated sound carrier is 4.5 mc ±1000 cycles above the frequency of the main picture carrier actually in use at the transmitter.

8. The radiated signals are horizontally polarized.

9. The power of the aural-signal transmitter is not less than 50% nor more than 70% of the peak power of the visual-signal transmitter.

Test Specifications — Group II

10. The color picture signal has the following composition:

$$E_m = E_Y' + \{E_Q' \sin(\omega t + 33°) + E_I' \cos(\omega t + 33°)\}$$

where

$$E_Q' = 0.41\,(E_B' - E_Y') + 0.48\,(E_R' - E_Y')$$

$$E_I' = -0.27\,(E_B' - E_Y') + 0.74\,(E_R' - E_Y')$$

$$E_Y' = 0.30\,E_R' + 0.59\,E_G' + 0.11\,E_B'$$

The phase of the color burst is $\sin(\omega t + 180°)$

Notes: For color-difference frequencies below 500 kc, the signal can be represented by

$$E_m = E_Y' + \left\{\frac{1}{1.14}\left[\frac{1}{1.78}\,(E_B' - E_Y')\sin\omega t + (E_R' - E_Y')\cos\omega t\right]\right\}$$

In these expressions the symbols have the following significance:

E_m is the total video voltage, corresponding to the scanning of a particular picture element, applied to the modulator of the picture transmitter.

E_Y' is the gamma-corrected voltage of the monochrome (black-and-white) portion of the color picture signal, corresponding to the given picture element.

E_R', E_G', and E_B' are the gamma-corrected voltages corresponding to the red, green and blue signals intended for the color picture tube, during the scanning of the given picture element.

E_Q' and E_I' are the two gamma-corrected orthogonal components of the chrominance signal corresponding, respectively, to the narrow-band and wide-band axes.

ω is 2π times the frequency of the chrominance subcarrier. The phase reference of this frequency is the color synchronizing signal (see Specif. 21 below) which corresponds to amplitude modulation of a continuous sine wave of the form $\sin(\omega t + 180°)$ where t is the time.

The portion of each expression between brackets represents the chrominance subcarrier signal which carries the chrominance information.

It is recommended that field-test receivers incorporate a reserve of 10-db gain in the chrominance channel over the gain required by the above expressions.

11. The primary colors referred to by E_R', E_G', and E_B' have the following chromaticities in the CIE system of specification:

	x	y
Red (R)	0.67	0.33
Green (G)	0.21	0.71
Blue (B)	0.14	0.08

12. The color signal is so proportioned that when the chrominance subcarrier vanishes, the chromaticity reproduced corresponds to Illuminant C ($x = 0.310$, $y = 0.316$).

13. Gamma correction is such that the desired pictorial result shall be obtained on a display device having a transfer gradient (gamma exponent) of 2.75. The equipment used shall be capable of an overall transfer gradient of unity with a display device having a transfer gradient of 2.75. The voltages E_Y', E_R', E_G', E_B', E_Q' and E_I' in the expression

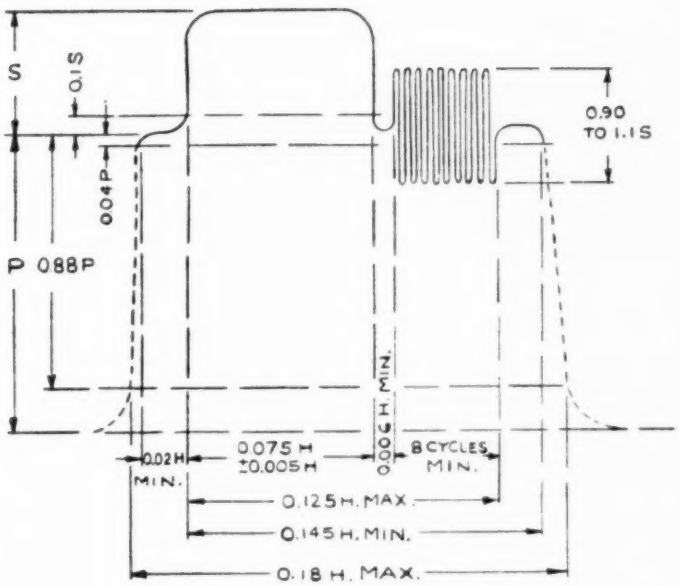

Fig. 9. Revised specifications for field test of NTSC compatible color television.

NOTES

1. The radiated signal envelope shall correspond to the modulating signal of the above figure, as modified by the transmission characteristics of Specif. 6.
2. The burst frequency shall be the frequency specified for the chrominance subcarrier. The tolerance on the frequency shall be ±0.0003% with a maximum rate of change of frequency not to exceed $\frac{1}{10}$ cycle/sec/sec.
3. The horizontal scanning frequency shall be 2/455 times the burst frequency.
4. Burst follows each horizontal pulse, but is omitted following the equalizing pulses and during the broad vertical pulses.
5. Vertical blanking 0.07 to 0.08 v.
6. The dimensions specified for the burst determine the times of starting and stopping the burst, but not its phase.
7. Dimension P represents the peak-to-peak excursion of the luminance signal, but does not include the chrominance signal.

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of Specif. 10, above, refer to the gamma-corrected signals.

14. The color subcarrier frequency is 3.579545 mc ±0.0003% with a maximum rate of change not to exceed $\frac{1}{10}$ cycle/sec/sec.

15. The horizontal scanning frequency is $\frac{2}{455}$ times the color subcarrier frequency. This corresponds nominally to 15,750 cycles/sec (the actual value is 15,734.264 ± 0.047 cycles/sec).

16. The bandwidth assigned to the monochrome signal E_Y' is in accordance with the FCC standard for black-and-white transmissions, as noted in Specif. 6 above.

17. The bandwidth assigned prior to modulation to the color-difference signals E_Q' and E_I' is given by Table I.

18. E_Y', E_R', E_G', E_B', E_Q', and E_I' are all matched to each other in time to within ±0.05 μsec. This is a tentative

Table I

Q-Channel bandwidth
at 400 kc less than 2 db down
at 500 kc less than 6 db down
at 600 kc at least 6 db down
I-Channel bandwidth
at 1.3 mc less than 2 db down
at 3.6 mc at least 20 db down

tolerance to be established definitely later.

19. The overall transmission bandwidth assigned to the modulated chrominance subcarrier shall extend to at least 1.5 mc below the chrominance subcarrier frequency and to at least 0.6 mc above the chrominance subcarrier frequency, at an attenuation of 2 db.

20. A sine wave, introduced at those terminals of the transmitter which are normally fed the color picture signal, shall produce a radiated signal having an envelope time delay, relative to 0.1 mc, of zero microseconds up to a frequency of 2.5 mc; and then linearly decreasing to 4.3 mc so as to be equal to -0.26 μsec at 3.579545 mc. The tolerance on all these delays shall be ± 0.05 μsec relative to the delay at 0.1 mc.

21. The color synchronizing signal is that specified in Fig. 9.

22. The field strength measured at any frequency beyond the limits of the assigned channel shall be at least 60 db below the peak carrier level.

Eidophor System of Theater Television

By EARL I. SPONABLE

The Eidophor, or Fischer, theater television system is described in an introductory way, then as installed at the Twentieth Century-Fox home office theater a year ago for exhibition shows for exhibitors and the press.

THE INITIAL CONCEPT of the Eidophor System started some thirteen years ago when Professor Dr. Fritz Fischer, working at the Swiss Federal Polytechnical Institute in Zurich, applied for a patent on a new and radically different idea for obtaining projected television pictures. His consideration of the problem led him to the conclusion — similarly reached by others — that in order to have a theater-sized picture of adequate brightness it would be necessary to employ a high-intensity arc as the light source. His thinking was thus along the lines of a standard motion picture projection unit, and the first effort to construct such a device, though the result was large and cumbersome, followed this general plan. He then reviewed possible means for controlling this light beam. The modulating units which had previously been employed in similar arrangements by others had not been particularly successful, and Prof. Fischer conceived the idea of making use of optical principles first enunciated by Foucault as a means for studying the surface configurations of concave telescope mirrors. These principles had later been extended by Toepler, who observed the difference in refractive index in air caused by heat waves in the optical system. Since Toepler's work in the early 1860's, this type of optical system has been frequently referred to as the "Toepler Schlieren" or simply "schlieren" system. (Schlieren is a German word meaning "streaks" or "striae.") An understanding of these optical principles is necessary in understanding the Eidophor system, since this is the heart of the matter, and it may best be explained in terms of the earliest of Prof. Fischer's models. While this early unit was unsuccessful, it did prove

Presented as an engineering exhibit at the theater television hearing before the Federal Communications Commission in October 1952, by Earl I. Sponable, Twentieth Century-Fox Film Corp., 460 W. 54 St., New York 19, N.Y. The engineering exhibits were presented under the joint auspices of the Motion Picture Association of America, Inc., and the National Exhibitors Theatre Television Committee.

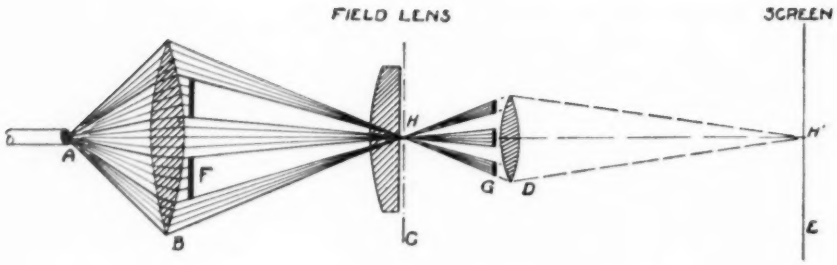

Fig. 1. Optical arrangement of schlieren system.

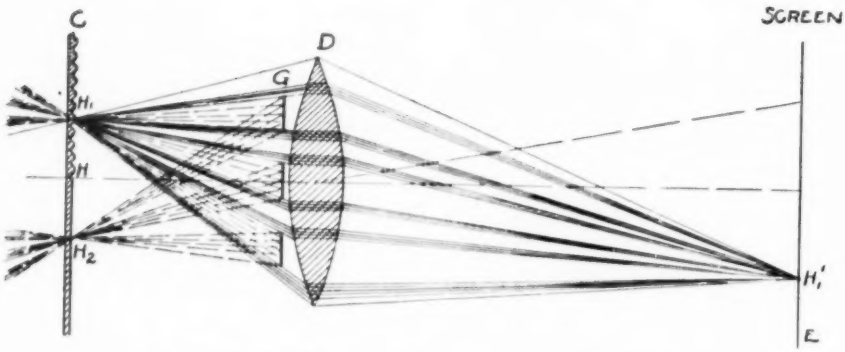

Fig. 2. Eidophor liquid as diffracting agent at image plane.

the workability of the basic ideas and led to the development of later models which performed satisfactorily.

Figure 1 is a schematic of this optical arrangement. The positive crater A of the arc lamp together with condenser lens B produces uniform illumination of the plane C; the light-modulating or controlling medium is placed in this plane between two bar-and-slit systems F and G. A field lens is so arranged that it images system F upon the bars of system G, at the same time insuring correct illumination of each and every point on the controlling medium. By way of example, the point H is illuminated in such a manner that the incident light beams passing through the slits of system F impinge upon the opaque bars of system G. The image point H is located in the image plane C of the objective lens D. This projection lens would thus image the point H as point H′ on a projection screen E. This is however impossible since the illuminating light beams are blocked off by the bars of system G. If, however, the control medium located in the image plane C is deformed in a suitable manner, diffraction of the incident light can be effected, and the diffracted parts of the beams may be made to pass through the slits of system G and reach the projection screen as image-forming light.

Figure 2 shows an oil layer of minute thickness at the image plane C (shown also in Fig. 1). This layer of liquid, called the Eidophor liquid, takes the place of the usual motion picture film in the film gate, as far as the optical

considerations are concerned. This oil layer, by way of illustration, might be supported by a glass plate.

It has been pointed out that the incident illumination of every image point is blanked off by the strips of the bar system shown as G (in Figs. 1 and 2). Since every point of the oil layer is illuminated and since each light beam traversing the layer is prevented, by the bars of G, from reaching the lens when the oil layer is of uniform thickness and is homogeneous, then under this condition no light will reach the screen. There remains then the problem of creating an image record in the form of some optical inhomogeneity which will cause the oil layer, point by point, to diffract the light beam through the slits of G. This is done by means of an electron beam from an electron gun which scans the oil layer and forms thereon a picture raster. The electron gun deposits electric charges point by point corresponding to the scanned picture and these charges cause minute corrugations in the surface of the oil layer. Where the surface is corrugated as at H_1 on surface C in Fig. 2, the light rays issuing from any such image point are diffracted, and part of the light which normally illuminates the bars of stop G then passes through the slits and produces illumination at the conjugate point H'_1 on the projection screen. This illumination will become more intense the more the Eidophor liquid surface is distorted, and we have therefore a means of reproducing point by point and line by line a television picture raster on a full-sized screen.

Figure 3 shows the relation between the distribution A of brightness along the line of the image to be reproduced and the wave-shaped deformation B of the surface of the Eidophor layer. The deviation of the envelope of the deformation curve from the original smooth surface is proportional to the desired brightness value.

The principle of the Eidophor method

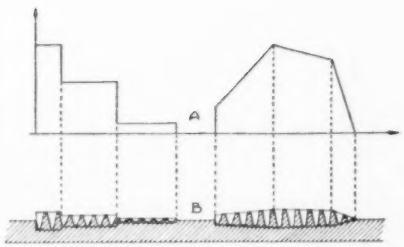

Fig. 3. Relation between distribution of image brightness (A) and deformation of Eidophor surface (B).

resides in modulating the cathode beam scanning the Eidophor surface by the video signal in such a manner that the deformations are proportional to the instantaneous value of the video signal. These wave-shaped deformations are brought about by the periodically varying distribution of electrical charges as stated above. These charges deposited on the oil surface by the cathode beam cause deformation by means of electrostatic forces. The wavelength of these deformations is always constant and lies in the neighborhood of 0.1 mm. The height of the waves is proportional to the video signal. As the illumination of the image points on the projection screen is always proportional to the height of the waves at the corresponding point on the Eidophor, the distribution of light over the projection screen corresponds to the video signal and thus to the object to be reproduced.

The deformation commences at the moment in which the cathode beam scans a particular point of the image. By a suitable choice of the conductivity and viscosity of the Eidophor oil, it is possible to conserve the deformation for a considerable part of the image-scanning period so that it disappears but shortly before the occurrence of the succeeding scanning. In other words, the illumination of the projection screen is maintained for this part of the scanning period; this represents a substantial light storage

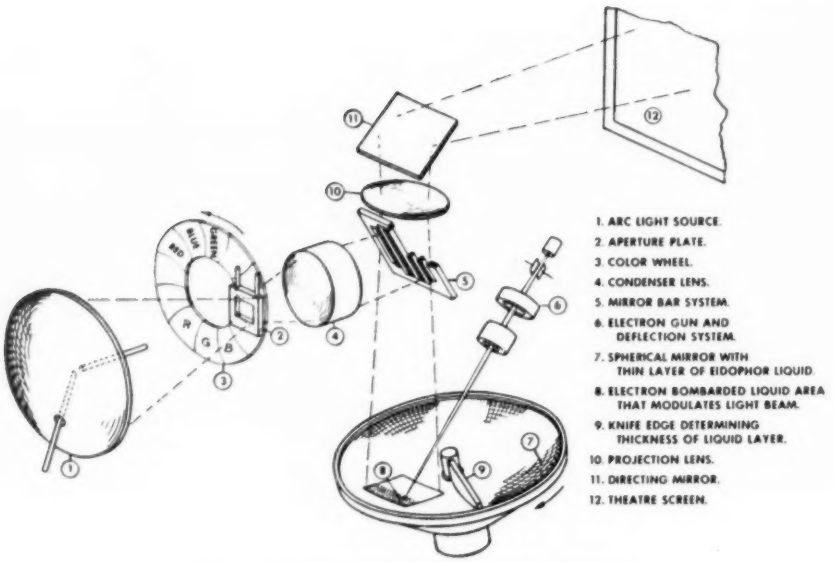
1. ARC LIGHT SOURCE.
2. APERTURE PLATE.
3. COLOR WHEEL.
4. CONDENSER LENS.
5. MIRROR BAR SYSTEM.
6. ELECTRON GUN AND DEFLECTION SYSTEM.
7. SPHERICAL MIRROR WITH THIN LAYER OF EIDOPHOR LIQUID.
8. ELECTRON BOMBARDED LIQUID AREA THAT MODULATES LIGHT BEAM.
9. KNIFE EDGE DETERMINING THICKNESS OF LIQUID LAYER.
10. PROJECTION LENS.
11. DIRECTING MIRROR.
12. THEATRE SCREEN.

Fig. 4. Essential components of the projector.

effect. The light storage effect is of primary importance when considering the efficiency of the Eidophor method, which is appreciably in excess of the increase in efficiency which may be achieved with ordinary cathode-ray tubes by using the afterglow of the phosphor layer.

After the completion of the first prototype model and the study of the data gained from it, it was decided to build a second and improved unit. Before this was finished Dr. Fischer died, and the work was carried on by his associates under the direction of Professor Baumann and Dr. Thiemann. With the second unit large-screen images were produced and the results were sufficiently promising to justify building a third and much smaller prototype with a new layout of the schlieren optics utilizing only one bar system and a spherical mirror. This third prototype was first operated in December 1950; it showed black-and-white, large-screen television pictures and fulfilled all expectations as to its performance. (A description of the early equipment has been published in this *Journal*.[1] Dr. Thiemann published an extensive article in 1949,[2] and an article by Prof. Baumann[3] is reprinted in succeeding pages of this *Journal*.)

Since the time had come when the emphasis must be on practical design, an arrangement was made between the Institute and Dr. Edgar Gretener, A.G. of Zurich whereby the latter organization would undertake the practical adaptation and commercialization of the equipment. Discussions culminating in a contractual relationship were negotiated with Twentieth Century-Fox; demonstrations were given, and technical conferences held, and it was determined that, to compete with the present state of the motion picture art, large-screen television pictures should be in color.

An arrangement was made with the Columbia Broadcasting System to make use of its field-sequential color knowledge and techniques. This method offers to

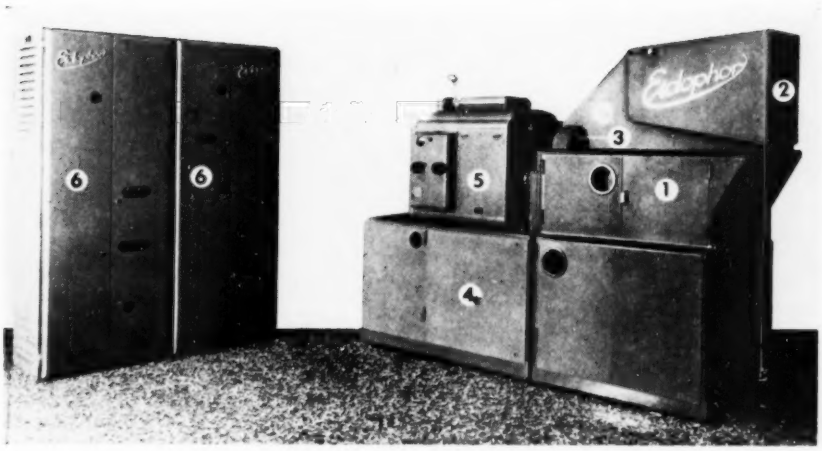

Fig. 5. Eidophor large-screen color television projection equipment: (1) Eidophor projector; (2) projection light beam hood; (3) color wheel; (4) auxiliary services (vacuum pump, thermostat and system for Eidophor cooling); (5) projection lamp (Ventarc-type); and (6) television receiver circuits.

the observer red, blue and green component images with identical contours in rapid alternating succession. The rapid succession of these three component images leads to additive color mixture within the eye of the observer, providing of course that the alternation of the component images is done with sufficient rapidity.

In order to convert the black-and-white Eidophor projector to the field-sequential color system, it is only necessary to insert the usual filter wheel in the arc beam at a point conjugate to the image plane, and then to cause the filter wheel to rotate in synchronism with a similar wheel in the camera. If the appropriate color signals are then fed to the electron gun, appropriate colored images will be projected to the screen. Since the field-sequential color system has already been approved by the Commission and has been the subject of extensive prior exhibits,[4] it seems unnecessary to describe it more fully here. A schematic drawing of the arrangement of the essential components of the projector is shown in Fig. 4.

The third prototype unit was modified for color and operated in Zurich in September 1951, and was shown November 12 to an audience of some 55 persons consisting of representatives of motion picture exhibitors, industry executives, and the interested press. This equipment was subsequently shipped to New York and installed in the home office theatre of Twentieth Century-Fox, where it was ready for operation in April 1952. Although still an engineering model, its performance was most gratifying and many demonstrations were given with it. For this particular unit the technical standards were as follows:

Field repetition rate	150/sec
Frame repetition rate	75/sec
Interlace	2/1
Color picture repetition rate	25/sec
Number scanning lines (total)	525

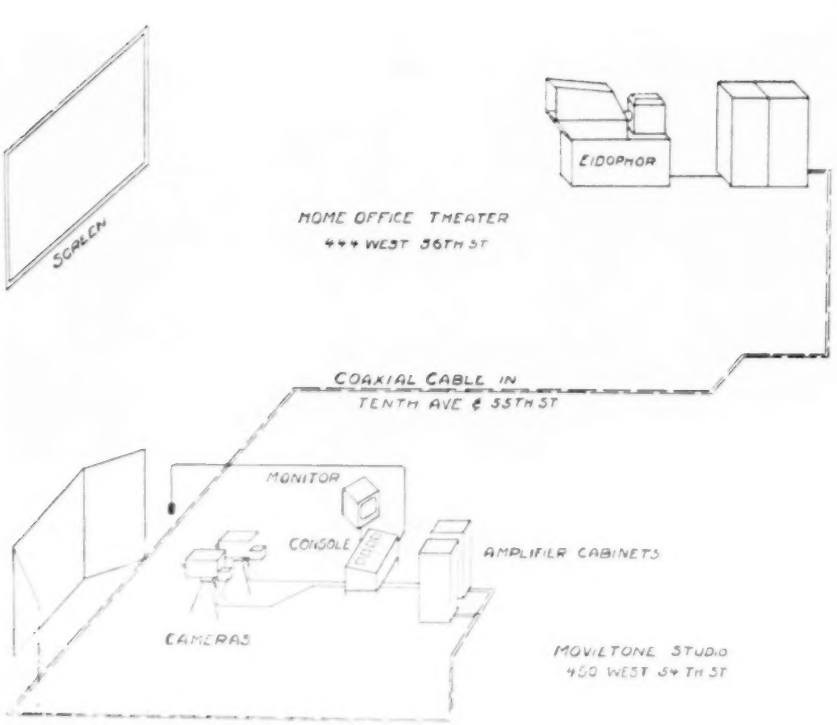

Fig. 6. Typical complete Eidophor system.

Horizontal scanning frequency	39,375/sec
Horizontal blanking	20% (approx.)
Vertical blanking	10% (approx.)
Horizontal definition (system)	400 lines (approx.)
Video bandpass (system)	12 mc (approx.)
Field color sequence	red, blue, green
Highlight screen brightness	6 ft-L (approx.)
Screen size	11 × 15 ft
Throw	68 ft

Figure 5 shows the experimental Eidophor equipment as set up in New York, and shows particularly how the auxiliary equipment (required to maintain the Eidophor liquid at constant temperature, and the cathode-ray system under constant low pressure) has been integrated into one compact unit. Appropriate automatic controls and protective devices have also been incorporated into the system, thus making the equipment comparable to an ordinary motion picture projector in its operational facility.

In order to give a more comprehensive picture of a typical complete system, a schematic diagram is shown in Fig. 6 of the arrangement of the various functional components used for demonstration purposes. This diagram is illustrative of a situation in which a studio sends the video signal to the theater, or theaters, over suitable transmission cables or radio relay links.

It may be appropriate to point out here that the Eidophor system is by no means limited to field-sequential color. It has been suggested (and development

work is being done in this direction) that several picture rasters be laid down in appropriate geometric relationship on the one mirror surface, each raster corresponding to one of the primary colors chosen for the particular process. Thus either a two-, three-, or four-color additive simultaneous projection process is theoretically possible, with consequent economy of light, but with obvious complication in equipment design.

The development of the Eidophor system has now reached a point where the quality of reproduction can be fairly judged. As a result of observations of this system in operation and of the favorable comments received from others, plans are now being made for the development and production of a commercial model.

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The Fischer Large-Screen Projection System

By E. BAUMANN

The paper describes the Fischer system of large-screen television projection which makes use of an "Eidophor" liquid. Consideration is given to the brightness requirements, and the principles of the schlieren optical system are discussed together with the manner in which the Eidophor functions. The technical problems involved are dealt with and the results obtained with the third prototype examined.

1. Introduction

There are many possibilities for the solution of the difficult problem of large-screen projection of television pictures, and it would almost be foolish to consider one or the other method as absolutely best. The system which is to be discussed here has been influenced from its beginnings by a clear and definite aim: the television picture should, in every respect, be of the same quality as the modern motion picture, i.e., of equal brightness, size, definition and gradation. I realize of course that this is a very ambitious aim and I would by no means maintain that it has already been reached at present. On the other hand, I should like to make it clear that all our work has always been done with this aim in view. And as the development proceeds, the fundamental difficulties that might hinder the final success grow smaller and smaller.

You will allow me a short summing up of how the system has been developed so far. Professor Dr. F. Fischer applied for a patent for his basic ideas in November, 1939, and started their practical development in the AFIF (Department of Applied Physics of the Swiss Federal Institute of Technology, Section of Industrial Research). With his almost unlimited courage he tackled the underlying problems that had never been treated before. He constructed the first prototype of the projector which was first operated in the year 1944. The results of this construction, however, were by no means encouraging and did not by far fulfil the hopes that were put in it. The difficulties, it is true, were not of such nature as to render any further pursuit of the idea absolutely hope-

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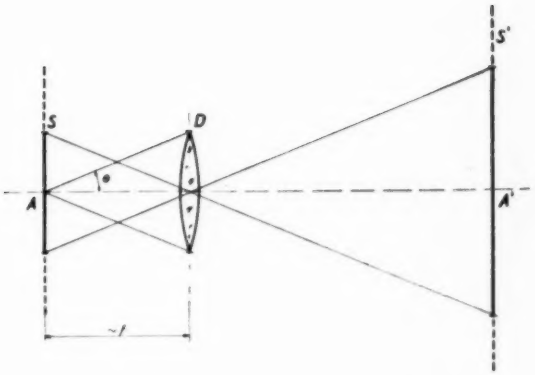


Fig. 1. Principle of projection. The projection lens of diameter D is at a distance from S of about f = focal length (for lateral magnifications of $m = \sqrt{A'/A} > 1$).

less, but it seemed clear that the success could only be reached at a much greater expense of research and development than was originally thought. But Prof. Fischer did not allow himself to be troubled and courageously started to design a second prototype. Already the outward appearance of the second projector made it clear that his bold original plans had been revised. Still the equipment was very large and complicated and there could hardly be any serious hope of its practical adoption in that shape. But the first target that had to be reached was the proof that the system could work at all. When Prof. Fischer's untimely death in the year 1947 brought his tireless activity to an end, the second projector was not yet in operation and the main problems were by no means solved. We do not lessen Prof. Fischer's lasting merits as a pioneer, if we say that only the development made after his death gave the system a basis for its practical adoption. The success is in the first place due to the optimism and untiring energy of his former collaborators, Dr. H Thiemann, F. Mast, K. Hetzel, Dr. F. Held and Dr. R. Petermann.

On the occasion of the International Television Convention in the summer of 1948, the operation of the second prototype could be demonstrated. The quality of the pictures which was reached then gave proof of considerable progress, and helped to strengthen very widely the hope of final success. Those responsible were convinced that the new experiences and discoveries would furnish the essential data for a third prototype which, considerably simpler and smaller than the second, should come much nearer to a solution that could be practically adopted. This third prototype which was first operated in December, 1950, fulfilled our hopes in every essential point.

Since in this stage the stress lay on the problems of practical adaptation, it was time to secure the help of a competent industrial producer and to leave to him the responsibility for this difficult task. This was done in the spring of this year and the rights for the utilization of our system now lie with the firm Dr. E. Gretener A.G., in Zurich. As a university department we have retained the possibility to further the development in close collaboration with the firm.

2. Theoretical Requirements of the System

It will be known that the Eidophor system makes use of a light source for the production of the screen picture. The brightness, therefore, as in cinema projection, depends largely on the power of this light source. This fact and the relatively great efficiency of the system

Table I. Screen Areas and Light Fluxes in Some Cinemas on the Continent

Cinema	Seats	Screen size (picture width) in ft	Screen area, sq m	Projection distance, m	Projection angle, deg	Light flux (ASA), lm
Kapitol in Bern	720	19	4.2 × 5.6 = 23.5	34	17	3161
Urban in Zürich	1150	22	5 × 6.7 = 33.5	31.5	12	4506
Rex in Paris	3200	33	7.5 × 10 = 75	45	21	10087
Marignan in Paris	1800	40	9 × 12 = 108	33.5	23	14526
Le Régent in Neuilly-sur-Seine	1400	19	4.2 × 5.6 = 23.5	26	15	3161
Cinéac des Ternes in Paris	600	19	4.2 × 5.6 = 23.5	22	18	3161
Cinéac in Strasbourg	500	16	3.5 × 4.7 = 16.5	21	23	2219
Royal in Rabat	1500	20	4.5 × 6 = 27	39	20	3631
Palazzo del Cinema in Venice	1400	33	7.5 × 10 = 75	34	12	10087
Palladium in Copenhagen	1400	27	6 × 8 = 48	35	5	6466
Asta at The Hague	1200	22	5 × 6.7 = 33.5	27	3	4506
Capitol at The Hague	1000	20	4.5 × 6 = 27	23.5	17	3631

enable us to produce very powerful light fluxes which are sufficient even for the screens of the largest theatres. A further advantage lies in the possibility of adapting the optical layout of the system to the architectural necessities of the various theatres and to install the projector in the existing booth, as it is commonly done with ordinary cinema equipments.

The brightness B_s of the screen required in good cinema projection amounts to about 10 ft-L. For a given screen area A' the required light flux can be computed as follows

$$\phi_s = \frac{\pi}{0.8} A' B_s \qquad (1)$$

The factor 0.8 is the coefficient of remission of the screen, as for an ordinary medium quality cinema screen with diffuse reflexion.

Table I states the screen areas used in some well-known cinemas on the Continent. The light flux necessary for these screens according to Eq. 1 is given as well. The table shows that $\phi_s = 10{,}000$ lm are necessary for the largest theatres. This means an enormous light-flux in television, and we have now to consider how it can be produced.

We shall assume, without going into details now, that the projection of our picture follows exactly the same principles as cinematographic projection. Only we have the Eidophor surface instead of the film and we shall therefore speak of the Eidophor picture. In Fig. 1 the Eidophor picture of the area A lies in the plane S, the projection screen of the area A' in the plane S'. The total light flux that falls on the screen is equal to the light flux passing the lens. From every point of the Eidophor picture a light-pencil of half the opening angle, 2θ, hits the lens; thus the light flux can be computed to be

$$\phi_s = \pi \cdot B \cdot A \cdot \sin^2\theta \qquad (2)$$

B being the brightness of the Eidophor picture, and $\sin\theta$ being $\sim D/2f$,

$$\phi_s = \frac{\pi}{4} BA\left(\frac{D}{f}\right)^2 \qquad (3)$$

$(D/f)^{-1}$ is called the f-number of the lens.

If we put the expression from (1) for ϕ_s, and using $m = \sqrt{A'/A}$ we get:

$$B = \frac{m^2}{0.2}\left(\frac{f}{D}\right)^2 \cdot B_s \qquad (4)$$

From (4) we can compute the necessary brightness B of the Eidophor picture, if we know the brightness of the screen. If the screen area $A' = 75$ sq m $= 7.5 \times 10$ sq m and the Eidophor picture area $A = 7.5 \times 10$ sq cm $= 75$ sq cm, we get $m = 100$. In cinema projection the area A has a fixed value and is much smaller namely 3.5 sq cm, which makes $m = 463$. Table II presents the values of B for some values of D/f for both cinema and television.

Table II

D/f	$m = 100$, B	$m = 462$, B
1:1	175	3,740
1:2	700	15,000
1:5.5	5,250	114,000

B in candles/sq cm.

It follows that the area A plays a decisive part, and if we compare with cinema projection we see that in television we have the advantage of having this area 20 to 30 times larger. In consequence, we can use apertures (of about 1:5.5) which do not present great optical difficulties even in more complicated systems, and which allow quite reasonable lens diameters. However, the projection cannot be effected without losses, as we have assumed so far. The losses that we have to take into account are very considerable and may reach the factor of 10 (and more) against about three for the cinema. The brightness of the Eidophor picture actually required for the production of 10,000 lm is, therefore, in our example for an f/number of 5.5 about 50,000 to 70,000 c/sq cm.

But modern arc lamps, such as the Ventarc lamp developed by the firm Dr. E. Gretener, A.G., can produce average brilliancies in the crater up to and above 120,000 c/sq cm, so that the conditions in this respect are fairly favourable.

I should like to point out that the figures mentioned here refer to one single example. But according to the given practical requirements, all sorts of variations can be made. The only purpose of the figures given above is to show that the production of light fluxes as required in the largest theatres can be effected by existing means.

3. Description of the Optical System

The basis of our projection system is a kind of light valve and we shall presently see the elegant principles that govern the light control. The most important element is the so-called schlieren-optical system. Figure 2 shows the diagram of such a system. The image of a system of bars and slits, lying in the plane S and illuminated from the left, is projected by the schlieren-optical system O_s on to an analogous system of bars and slits lying in S'. As shown in our diagram, the images of the slits *1* and *2* fall on the bars *1'* and *2'*, and the images of the bars, a, b, c, on the slits a', b', c'. Under these circumstances no light is allowed to pass into the space to the right of S'. We now expand the system by joining a new lens O_p immediately behind S' (Fig. 3) and choose its focal length so as to project the image of a plane P near the schlieren lens O_s, on to the screen P'.

A small glass prism N is now placed on a point of the plane P. Consequently the light-pencil, passing N is deflected from its original direction according to the deflection angle of N. The rays of this pencil can therefore partly pass the bars *1'* and *2'* and are focused by the lens O_p on the screen in N', where they appear as a luminous point. The brightness of the point N' depends on how much of the light-pencil is allowed to pass bars *1'*, *2'*, and this varies according to the deflection angle of the prism. We

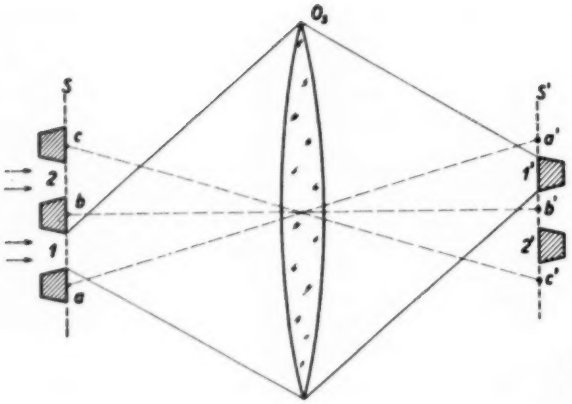


Fig. 2. Principle of a schlieren optical system.

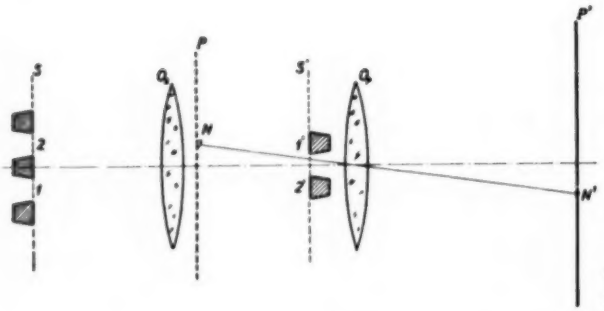


Fig. 3. Development of a schlieren optical system.

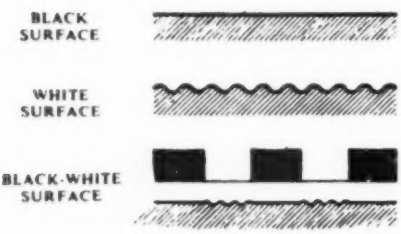


Fig. 4. Deformation of the Eidophor liquid.

now imagine the whole plane P to be covered with as many adjustable prisms as there are picture points on the picture to be projected. We can now control the brightness of any image point on the screen P' by suitably adjusting the deflection angles of the prisms. Our pictures are thus produced on a raster basis, i.e., they are composed of individual discrete picture points.

It was Prof. Fischer's ingenious idea to produce the prisms by depositing a rastered electric charge on a thin oil film. Under the influence of the electrostatic forces the surface of the oil is deformed and in this way the required raster elements are formed. The exact geometrical shape of these elements is important only in so far as it influences the light efficiency to a certain extent. The charge is applied point by point by means of a cathode beam, and we can thus employ the methods used in the technique of cathode-ray tubes. In order to produce a television picture, deformations in the form of sine-shaped wavetraces are engraved along the lines of the picture. The amplitude of the wave controls the brightness of the correspond-

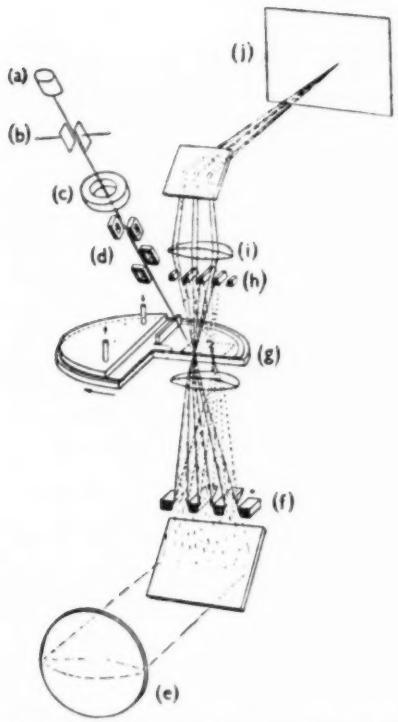


Fig. 5. Diagrammatic arrangement of the "Eidophor" projector.
(Based on the second prototype.)

(a) Electron gun
(b) Modulation grid
(c) Focusing coil
(d) Scanning coils
(e) Arc lamp
(f) Lower grating
(g) Eidophor
(h) Upper grating
(i) Objective lens
(j) Screen

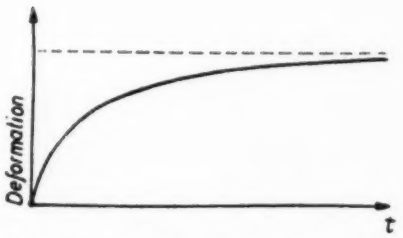
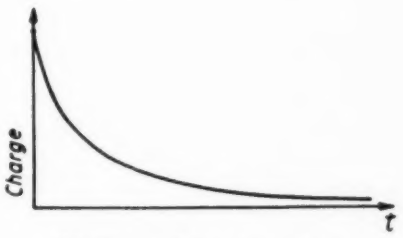
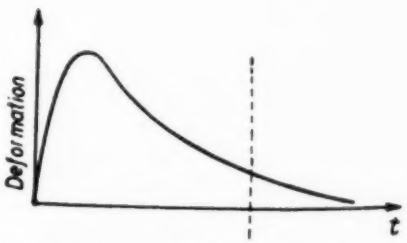


Fig. 6. (a) Build-up of the deformation for a nonconductive liquid.



(b) Decay of the charge in a conductive liquid.



(c) Development of the deformation in a conductive liquid.

ing part of the screen picture. In Fig. 4 the system is shown schematically.

An ideal reproduction equipment should be able to store the picture information for the duration of one picture period. This means that the deformations on the oil should remain for the duration of one picture period, but decay as quickly as possible after the period is over. This decay, however, is only possible if the electric charge that produces the mechanical forces decays as well. For this purpose, the oil, the Eidophor as Prof. Fischer has called it, has been made conductive. The deposited charges, therefore, decay according to a time law corresponding to an exponential function. The electric conductivity governs the time constant. The mechanical processes of the formation and the decay of the deformation are subject to a certain inertia. The decisive forces for this are the surface tension which tends to level out the surface of the liquid, and the viscosity

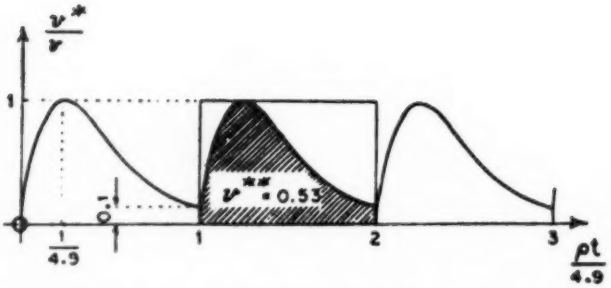


Fig. 7. Development of the deformation of the medium with time.

which takes the function of damping. If we watch one given image point we observe the following process: At the beginning of the image period, the cathode ray passing the image point deposits an electrical charge within a very short time $< 10^{-7}$ sec. The electrostatic forces become effective at once and the deformation of the surface begins according to an exponential law (cf. Fig. 6). The time constant is proportional to the quotient of the surface tension and the viscosity. For a nonconductive Eidophor the deformation would tend to reach a definite final value (Fig. 6a). As, however, the charge diminishes according to an exponential function, the forces causing the deformation are diminished as well (Fig. 6b), so that both causes result in a development of the deformation as illustrated in Fig. 6c. For a whole series of successive image periods, a development as illustrated in Fig. 7 results. For all practical purposes, a remainder of 10% of the deformation, at the end of the image period, is tolerable. This time law of the deformation allows an effective light-storage of about 70%.

As is easily seen, the Eidophor image constantly carries a certain average negative charge which exercises a constant average mechanical pressure on the oil surface. If the oil film were left to itself it would be pushed out of the image field in the course of time. To prevent this, the Eidophor carrier is slowly being turned so that the oil film in the image field is constantly renewed. Since the rotation is very slow, its influence on the image is practically nil.

The maximum amplitude of the deformation is only a few thousandths of a millimeter. Consequently, the oil surface must be of the highest quality as even the smallest deficiencies result in an undesirable brightening-up of the screen. Fortunately this trouble can be removed to a certain extent in a comparatively easy way. If the relationship between the dimension of the raster elements and the other dimensions of the schlieren-optical system is appropriately chosen, the deflection of the light is accompanied by diffraction, which allows for a schlieren system of lower imaging quality to be used successfully.

We can now make the second bar system *1′*, *2′* (Fig. 8) somewhat wider than the optical image of the slits *1*, *2*. The result is an elimination of the brightening-up effect of certain deformations, deformations exceeding a certain area now remaining without effect.

This new layout of the schlieren-optical system has made it possible to design a new simplified projector which is also reduced in size. Its diagram is shown in Fig. 9. The schlieren lens was replaced by a spherical mirror. Instead of two separate bar systems we now use a single one which comes twice in action. It consists of a number of mirror strips

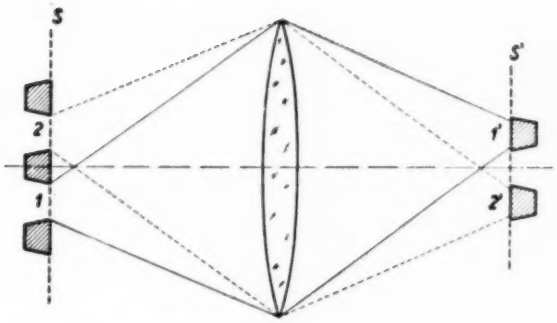


Fig. 8. Schlieren system using diffraction.

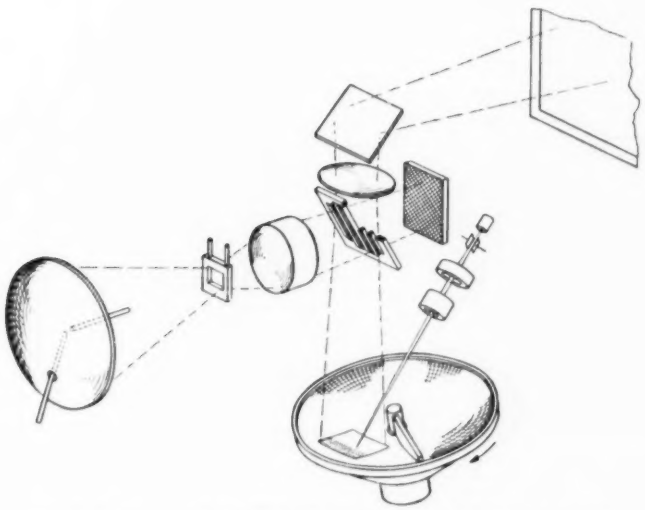


Fig. 9. Diagram of the Eidophor projector (third prototype).

which are fixed at twice the focal distance, at an angle of 45° with respect to the optical axis of the mirror. Thus the bar system carries its own image that is reflected by the mirror. The Eidophor picture itself is placed on the spherical mirror and again consists of a thin oil film. The mirror is now caused to rotate slowly and a straight radial ruler allows the passage of a quantity of oil necessary for the production of the picture carrier.

Optically the system works as follows: The mirror strips are illuminated by an arc lamp, the light-pencil of which is at a right angle to the axis of the spherical mirror. By an illuminating lens an image of the arc crater is formed on the Eidophor. The relative position of the bar system and the spherical mirror is so as to cause all the light to fall back on the arc, owing to the focusing power of the spherical mirror, as long as the Eidophor surface is absolutely smooth. But as soon as the Eidophor surface is deformed, the light is accordingly allowed to pass through the slits of the bar system and to enter the projection lens. It

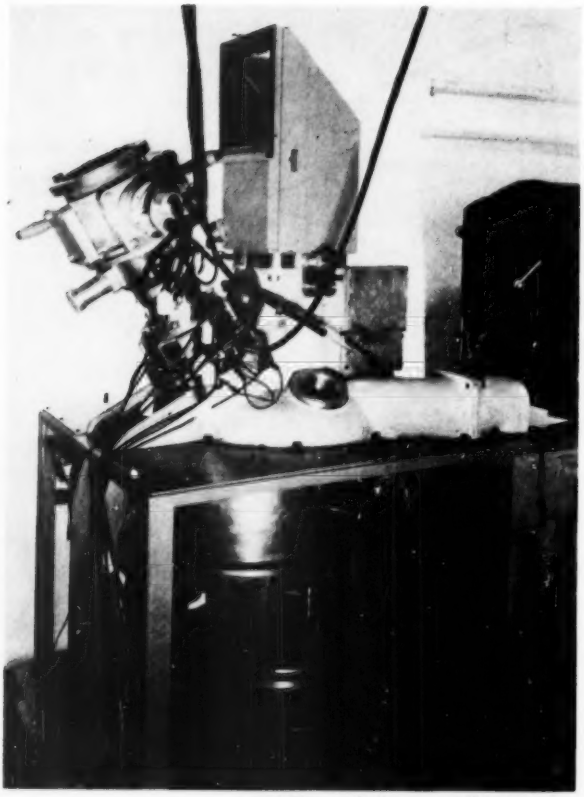
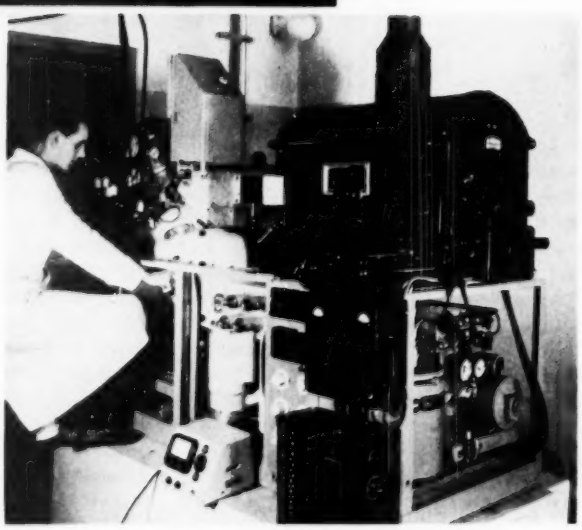


Fig. 10 (above). View of third prototype projector. The "electron gun" structure can be clearly seen, also the Eidophor container.



(Right) View of the projector from the rear. The arc lamp projector is prominent, and the high-vacuum equipment can be seen below it.

then reaches the screen by a deflecting mirror. Of course, full use is made of the diffraction optic and the edges of the mirror strips are, therefore, blackened and nonreflecting. The deposition of the charge on the oil film has been taken over from the old system without any change.

The principal advantages of the new system as compared with the old one are the following. Owing to the use of a reflecting optic, the light path through the schlieren system is now only half its original length. The diffraction optic also allows us to make use of a large image angle in the schlieren system and a consequent small focal length of the mirror. This leads to a much more convenient optical layout and to a considerable reduction of the outward size of the projector. Even now it does not take up more space than an ordinary cinema projector. This reduction in size is clearly illustrated by the fact that the distance of the two bar systems of the schlieren-optical system was about 3 m in the old projector whereas the distance between the reflecting bars and the mirror is only 75 cm in the new system. Also the cooling of the Eidophor liquid has been made easier, as the Eidophor picture itself can now be cooled. This, in turn, allows a reduction of the rotating speed of the mirror so that the production of interlaced pictures is possible without difficulties.

4. The Definition of the System

Having seen the underlying principles of the operation of this system we shall now discuss some of the most important details. A problem of the first importance is, of course, the question of definition. Contrary to certain other systems, the definition of the picture is totally independent of the light-capacity, which, of course, is a great advantage. We know that the pictures are rastered. The attainable limit of the resolving power is dependent on the number of the raster elements and this might be the cause of a certain limitation. But this is, in practice, by no means the case as it is possible to produce more than 1000 raster elements per line, a number which meets all requirements for the time being. The same can be said about the number of lines. We did not limit ourselves to any fixed number, and our system has been working at 392, 625, and 729 lines. The situation may be most clearly illustrated by saying that the system allows frequency bandwidths of 10 mc and more to have their entire picture information on the screen.

5. Production of Picture Raster

Contrary to the functioning of the ordinary cathode-ray tubes we do not use amplitude modulation but a kind of velocity modulation of the cathode ray. To produce the picture raster we have to deposit a periodic distribution of the charge along every line of the Eidophor picture, the magnitude of this charge being proportional to the brightness of every picture point.

The cathode ray which is of constant intensity shows a rectangular cross section on the oil surface. The height of this rectangle is the same as the width of one picture line, its width being about 10 to 20% of the height. As long as the cathode ray travels along the line with constant velocity, it will deposit per unit of length a constant charge on the surface, the density of this charge being proportional to the writing speed for a constant intensity of the beam. We can thus influence the density of the charge by varying the writing speed. If the speed is great, a small charge is deposited; if it is small the charge becomes proportionately greater. In order to produce the modulation, an alternating voltage of constant frequency is superimposed on the line-sweep voltage. The frequency of this additional voltage controls the dimension of the raster elements, the amplitude controlling the density of the charge deposited (cf.

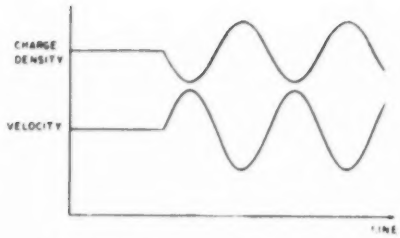


Fig. 11. Velocity modulation of the cathode ray.

Fig. 11). For the practical application of this modulating system it is useful to introduce the additional modulation velocity through separate plates. For the full control of the picture modulation, potentials of about 1 v are sufficient.

It can be seen from the way the raster is produced that it is very important that the size and shape of the cathode-ray spot remains unchanged over the whole picture area. Great care must therefore be given to an accurate focusing of the beam. Any widening of the spot causes the picture to grow darker, but the definition of the picture is hardly influenced by this. In order to obtain a constant rectangular shape of the spot, a mechanical tungsten diaphragm is placed in the cathode-ray optic in the crossover of the electrons in front of the cathode; the rectangular opening of the diaphragm is 0.1 × 0.015 mm (= 0.004 in. × 0.0006 in.). A magnetic lens projects the image of this opening electronically on the Eidophor surface at the scale 1:1. The considerable inclination of the cathode ray with respect to the picture plane demands, of course, adequate correcting potentials, which must be varied with great precision so as to assure good focusing. Moreover the ordinary difficulties that arise in any electron-optical system have to be overcome, and the actual limitation of the imaging quality of the crossover diaphragm lies in the aperture defects of the magnetic lens.

A valuable help in the solution of the whole problem is of course the constant beam current. In order to obtain the necessary density in the cathode beam, a special cathode was developed. Unfortunately the use of oxide-coated cathodes is impossible. The hydrocarbon vapours produced by the Eidophor would soon render such a cathode ineffective. For the time being pure tungsten is used as material for the cathode. Figure 12 shows a diagram of the cathode now used. The carrier of the emission is a tungsten bar which tapers at its back end to avoid a great loss of heat. This bolt is surrounded by a helix made of tungsten wire which serves to heat up the bar. The transmission of heat through the radiation of the heated helix does not suffice to bring the bolt to the high temperature required. We therefore apply to the helix a potential of adequate magnitude, negative with respect to the bolt. The bolt is thus submitted to an intense bombardment of electrons, which results in an additional heating up. By means of this device, for the size of the spot as given above, the beam current can reach about 20μA, an intensity which is sufficient for the full control of the television picture for line numbers and picture frequencies as they are used today. The picture and line deflections are effected magnetically. The dimensioning of the deflection elements was given special care, not only in connection with the problem of focusing, but also in order to reduce the distortion of the picture to a minimum.

6. The Eidophor Liquid

The technological problems that had to be solved in the development of the whole system were numerous and also very difficult in parts. The Eidophor liquid and the cathode beam are placed in a vacuum. In order to keep the pressure at about 10^{-5} to 10^{-4} mm Hg, a continuously operating oil-diffusion pump is mounted on the projector. Vacuum technique is so easily handled today that such a pump no longer pre-

sents any serious difficulties for the practical application of the projector.

A problem of fundamental importance was the production of a suitable Eidophor liquid because it had to meet requirements in many respects. In the beginning of the development it was a disputable point whether or not the oil would bear the intense bombardment of electrons of a velocity of about 20 kv without being destroyed. Indeed, some initial difficulties in this respect had to be overcome, but we are now sure that the Eidophor liquid can have a quite considerable life. If the oil was suitably chosen, no perceptible destruction was observed. Further qualities of the Eidophor liquid should be: very small vapour pressure (less than 10^{-5} mm Hg) optimal surface tension, dielectric constant, viscosity and electric conductivity. Of course the Eidophor should be as transparent as possible to prevent any influence on the colour of the screen picture. It is thus easily seen that the production of a suitable Eidophor liquid is a science of its own. Although many improvements are still to be desired, the results reached so far are quite satisfactory, especially if we consider the complicated nature of the problem.

It was mentioned before that the decay of the Eidophor deformation depends on the viscosity of the oil. As the viscosity, in turn, is largely dependent on the temperature, it is necessary to keep the temperature of the Eidophor constant during the period of its operation. This constancy however need not be very accurate, and an ordinary refrigerating machine, such as is commonly used in household refrigerators, can be used for this purpose.

The whole process of the production of these images is a very sensitive method to show very small optical inhomogeneities. Unfortunately there are not only the voluntarily produced inhomogeneities which serve for the production of the picture; the oil surface sometimes also shows undesired ones that appear as

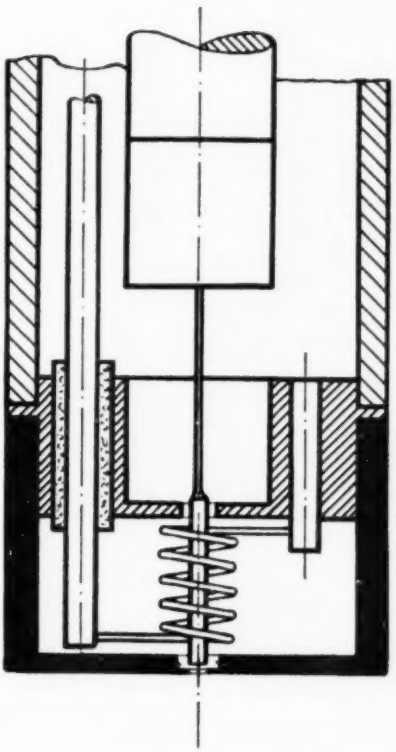


Fig. 12. Cross section of the cathode of the electron gun.

defects of the screen picture. Our worst enemy in this respect is any kind of dust that may enter whilst the system is put together and which may then be deposited on the optically sensitive parts. One of the most critical points is the spherical mirror which is at the same time the carrier of the Eidophor. The polish of its glass surface must be of an excellent quality and the metallizing (done by evaporation) can hardly be carried out carefully enough.

7. Conclusions

The results that have so far been reached with the third prototype can be described as follows: The laboratory

equipment is capable of projecting 4000 to 4500 lm on the screen. The contrast ratio between "black screen" and "white screen" is 1:200 to 1:400. The producible contrast in a picture is naturally largely influenced by the projection room, since the quantity of ambient light brightening up the dark parts of the picture depends on the nature of this room. The subjective impression that is given by the picture can quite well be compared with that of an ordinary motion picture. Gradation and definition will of course vary according to the quality of the picture source. Experience has shown that the observer has a tendency to judge the gradation of large pictures much more severely than the one of an ordinary home set. A very careful electrical correction is therefore necessary. With respect to definition no final verdict can yet be given, but interlaced pictures of 625 lines have yielded quite encouraging results. It is certain that any limits of the quality of the picture lie for the time being in the picture source and not in the projector. If there have been any troubles that could not be eliminated so far they have been due mostly to dust particles that could not be removed in time. But the continual progress observed justifies an optimistic outlook.

Our system will have to stand the practical test outside the laboratory before long. We know very well that the final practical success is still far away and we are far from underestimating the difficulties. But we also have every reason for looking ahead optimistically, hoping to have that bit of luck which is indispensable for any kind of undertaking.

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Review of Work on Dichroic Mirrors and Their Light-Dividing Characteristics

By MARY ELLEN WIDDOP

During World War Two, the application of thin films to glass surfaces progressed from experimental laboratory work to practical application in optical devices. At present, virtually all lenses are coated to reduce reflection. Plates coated with multilayer films, known as dichroic mirrors, are also being applied as efficient light dividers. The recent use of dichroic mirrors in experimental color television equipment is one of the best known applications. The purpose of this paper is to review briefly the interference phenomenon involved and to describe the results obtainable with several dichroic mirror designs.

ABOUT FIFTEEN years ago scientists began to experiment with the application of very thin multilayer films to glass, in order to reproduce the effects of color selective reflection and transmission strikingly exhibited in nature by certain crystals. Since that time, the use of this method to produce mirrors which efficiently divide light has become well known. One of the first applications of interference mirrors was in photocell monitoring of sound recording for motion pictures. During World War Two, quantities of dichroic interference mirrors were used in range finders and radar cameras. They are now used in both military and civilian products. In the RCA compatible system of color television, dichroic mirrors are used to divide light into primary colors and to combine the primary colors for monitoring.

Like the colors of soap bubbles, thin films of oil on water, oxide films on heated steel and certain crystals such as chlorate of potash, the light-dividing characteristics of dichroic mirrors result from interference in reflected and transmitted light. Interference films are also used to produce neutral light dividers, or to reduce reflection from glass. The films are applied to glass by the deposition of vaporized material on the glass surface, in a vacuum. The thickness of a deposited film may be controlled by observing the changes in intensity of a beam of light reflected from the glass, through a filter, into a photocell. The intensity fluctuates, reaching a maximum or minimum whenever the thickness of the deposited film is effectively equal to a multiple of $\frac{1}{4}$ of the wavelength of the control light.

To review the interference effects of thin films, we will first consider the effects produced by single thin films, as shown in Fig. 1. These diagrams represent plane parallel, nonabsorbing films on glass surfaces, and their effect on an incident light ray. The film thickness in both cases is effectively equal to $\frac{1}{4}$ of the wavelength of the incident light ray. The film in diagram (a) has an index of

Presented on October 7, 1952, at the Society's Convention at Washington, D.C., by Mary Ellen Widdop, Radio Corporation of America, RCA Victor Div., Engineering Products Dept., Camden 2, N.J.

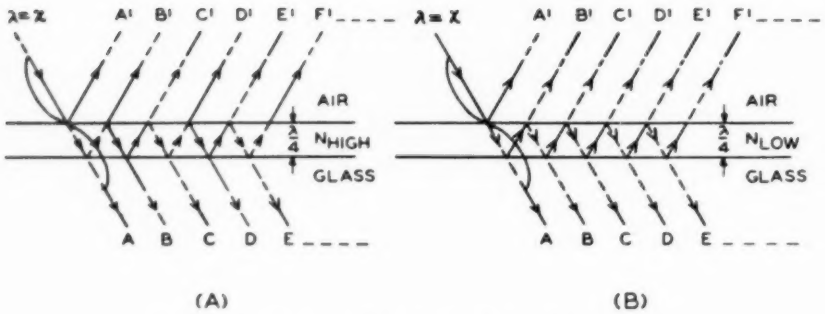

Fig. 1. Interference effects in single $\frac{1}{4}$ λ films on glass.

refraction higher than that of glass, while the film in diagram (b) has an index of refraction lower than that of glass.

Any light ray incident on such a film becomes the source of two sets of almost superimposed parallel rays. These rays tend to cancel or reinforce each other by destructive or constructive interference. The type of interference which occurs depends on the relative phase of the interfering rays. The phase of the reflected and transmitted rays is determined by the optical path through the film and by phase reversals which occur on reflection from a denser medium. In these diagrams, phase is indicated by solid and broken line segments. For simplicity, the angle of refraction is ignored.

The high-index film produces reinforcement for a specified wavelength in the reflected light and cancellation in the transmitted light. Here, the only phase change due to reflection from a denser medium occurs at the air-film boundary.

The successive rays, proceeding toward the right, are less and less intense; hence the effects of the first two reflected rays, and the first two transmitted rays, are dominating. The phase reversal of alternate succeeding rays modifies the effect of the first two rays, therefore neither cancellation nor reinforcement is complete.

In the low-index film, there is a phase change in the initial reflection from the air-film boundary and at each reflection from the film-glass boundary. As a result, an effective film thickness equal to $\frac{1}{4}$ of the wavelength here produces cancellation in the reflected light and reinforcement in the transmitted light.

The amplitude of the reflected rays, for a specified angle of incidence, is determined by the relative indices of refraction of the materials on either side of the boundary from which reflection occurs. Therefore, if the relative indices of refraction of the air, film and glass were of such value that the amplitude of the ray initially reflected at the air-film boundary equalled the sum of the amplitudes of the other reflected rays, no light of the specified wavelength would be reflected from the film in diagram (B), since the rays are 180° out of phase.

The maximum reflectance obtainable from a single film is determined by the index of refraction of the film. In order to increase the reflectance for a certain wavelength, multiple alternate layers of high- and low-index materials are applied. The film thickness for each layer is controlled so that the initial reflected rays, of the control wavelength, from each film boundary are in phase when they leave the film. The reflected intensity for that wavelength is then equal to the square of the sum of the amplitudes of the reflected rays.

A diagram representing a seven-layer

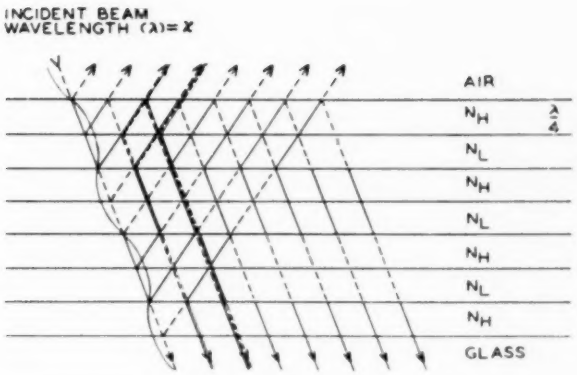

Fig. 2. Interference effects in a multilayer film on glass.

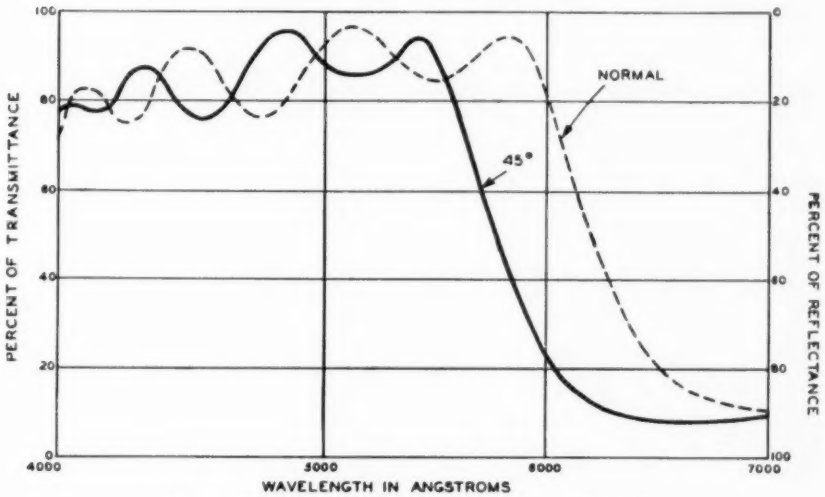

Fig. 3. Characteristics of a seven $\frac{1}{4}$ λ-layer dichroic.

film and its effect on an incident light ray is shown in Fig. 2. In this film, each layer is effectively equal in thickness to $\frac{1}{4}$ wavelength. The initial reflected rays from each boundary emerge from the film exactly in phase. The strongest transmitted rays resulting from interfilm reflections are 180° out of phase with the initial transmitted ray. In addition to the strongest set of reflected and transmitted rays, there are many weaker rays resulting from interfilm reflections. Some of these rays are out of phase with the stronger rays but since they are so much weaker they, of course, cannot cancel the effect of constructive interference in reflected light and destructive interference in transmitted light for wavelength X.

The film design shown in Fig. 2 is a standard design which, when composed of the materials most commonly used, reflects over 90% of the light at the control wavelength. The effect of this film on light of other wavelengths is determined by the relative phase of the reflective rays and of the transmitted rays as they leave the film. Transmission char-

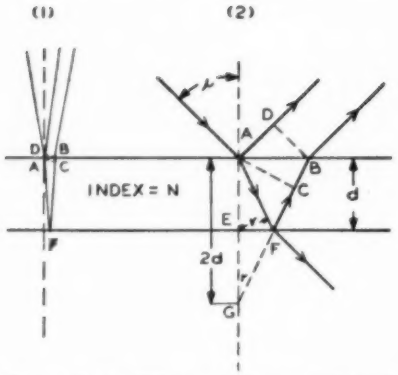

Fig. 4. Path difference of rays reflected from the two boundaries of a thin film.

acteristics in the visible range for a film of this design, controlled for maximum reflectance at 6350 A at 45° angle of incidence, are shown in Fig. 3. There is no appreciable absorption: therefore, all light not transmitted is reflected. A dichroic of this type is used to reflect red light in the color-television camera.

As shown in Fig. 3, the transmission curve shifts toward the short wavelength end of the spectrum when the angle of incidence is increased. This shift is due to the change of path difference with change of angle, making the film effectively thinner as the angle of incidence is increased. The path difference produced by a film is greatest at normal incidence. The diagrams in Fig. 4 represent two light rays incident on a thin film in air, and illustrate the factors which determine path difference. If a ray strikes the film at normal incidence, the path difference between the ray reflected from the first surface and those reflected from the second is equal to the product of the index of refraction of the film and twice the film thickness. Diagrams 1 and 2 represent rays incident on the film at two different angles. In both cases, dotted lines AC and DB represent successive positions of a wavefront. Therefore, the optical paths AD and CB must be equal, AD (in air) = N (CB), and the difference in optical path at wavefront DB, where the reflection from the second surface leaves the film, is equal to N (AFC). It can be shown that the path difference = N (2d cos r), thus as the angle of incidence increases, the angle of refraction increases, the cosine of r decreases and the path difference decreases.

Such a shift of light-dividing characteristics with change of angle of incidence is sometimes objectionable because of resultant shading in transmitted and reflected images. Shading from one side of an image to the other, due to large field angle, can be compensated for by tapering the deposited film. To do this, the glass is placed in the evaporating equipment at an angle to the plane of the evaporator, rather than parallel to it. The films deposited are then wedge shaped instead of plane parallel. The resultant mirror is then positioned in use so that the thickest part of the film receives light at the greatest angle.

By varying the number of deposited layers, the thickness of each layer, the control wavelength and the angle of control, a wide variety of dichroic mirrors is obtainable. In Figs. 5 and 6, transmission characteristics are shown for a number of designs used to fulfill various light dividing or combining requirements. These designs consist of various combinations of $\frac{1}{4}$-, $\frac{1}{2}$- and $\frac{3}{4}$-wavelength film thicknesses.

In general, designs made with layers thicker than $\frac{1}{4}$ wavelength have a narrower band of reflection than $\frac{1}{4}$-wavelength designs. The heavy solid line in Fig. 5 is the transmission curve for a mirror of the type used to reflect blue light in the color camera.

To illustrate a way in which the interference mirrors are used, a diagram of the optical system of an RCA Color-Television Camera is shown in Fig. 7. When light entering the camera through the lens system reaches the dichroic cross, red light is reflected from mirror J to totally reflecting mirror M and then to

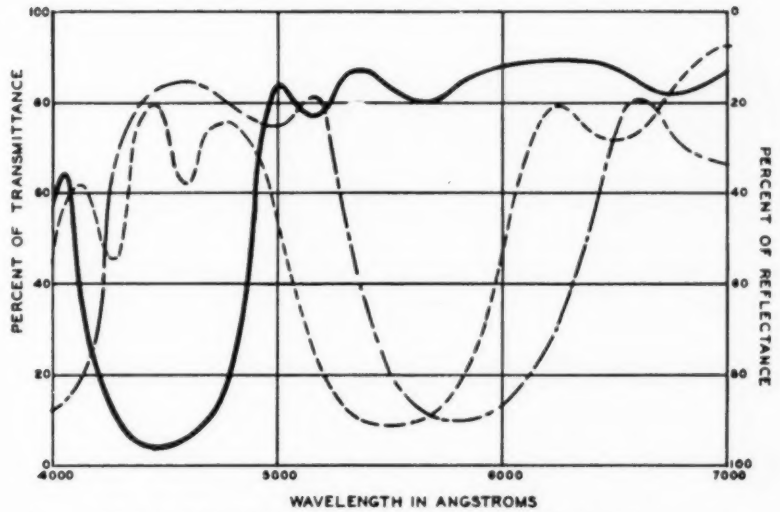

Fig. 5. Light-dividing characteristics of several dichroics.

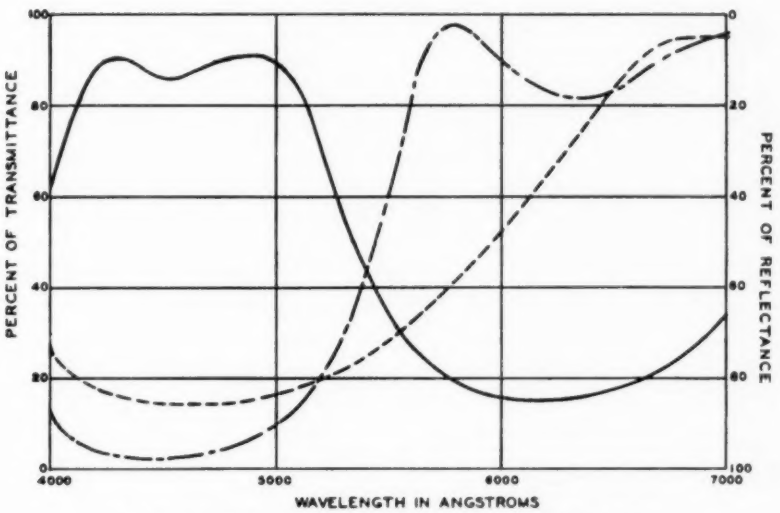

Fig. 6. Light-dividing characteristics of several dichroics.

the image orthicon in the red channel. Blue light is reflected from mirrors I and K, totally reflecting mirror L and then to the image orthicon in the blue channel. Green light passes through both mirrors to the image orthicon in the green channel. Each reflector efficiently transmits the other two primary colors. In this application, the dichroics are assembled in sandwiches with the reflecting surface on the inside, covered by another plate of the same thickness as that on which

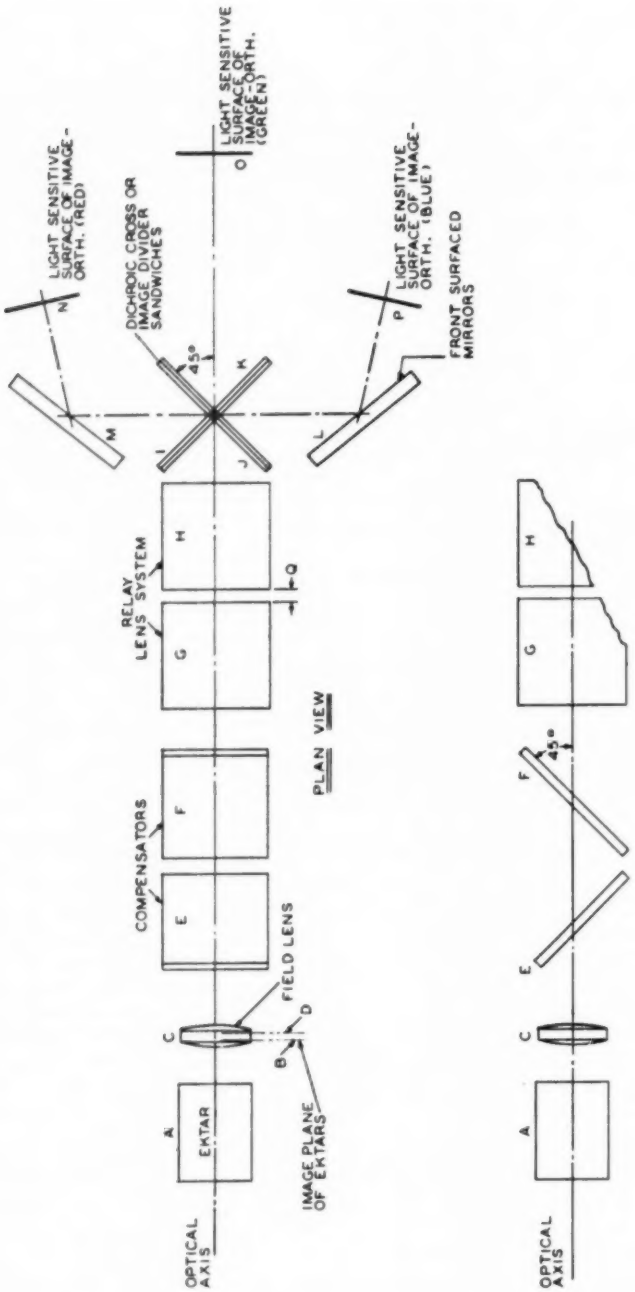

Fig. 7. Optical system of color camera.

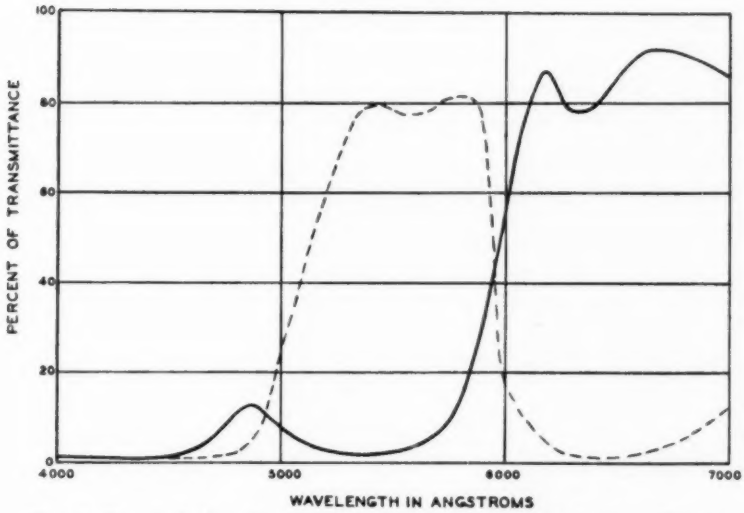

Fig. 8. Transmission characteristics of absorption-interference filters.

the dichroic film is deposited. The light path through the glass is then equal for all channels. The blue reflecting mirrors are carefully aligned so that the reflecting surfaces are in one plane and perpendicular to the red reflecting surface. With this arrangement, astigmatism introduced by the glass can be compensated for by placing two plates, E and F, at right angles to each other in front of the relay lens. The line of intersection of these plates is at right angles to the center line of the optical system and to the line of intersection of the dichroics.*

Materials which absorb light can sometimes be used advantageously in interference films. In Fig. 8, transmission characteristics of efficient red and green transmission filters are shown. These filters are made by depositing alternate layers of high- and low-index materials on glass, but in this case one of the materials used has the combined properties of very high index of refraction and strong absorption in the blue region of the spectrum. In the resultant films, blue light is removed by interference and absorption while the red and green portions of the spectrum are efficiently divided by interference.

When the reflected and transmitted light is to be divided in a way which is difficult, or impossible, to achieve with any single film design, sets of layers may be combined on one plate. For the final characteristics of a film to be the product of two different designs, the sets of layers must be separated from each other sufficiently to prevent much of the interference between the sets. The curve shown by the broken line in Fig. 9 is that of a plate coated with two sets of layers, one having peak reflectance for blue light and the other having peak reflectance for red light. In this case, the sets of layers were separated from each other by a thick evaporated layer of material. The solid-line curve in Fig. 9 is the resultant characteristic of two similar sets of layers deposited on opposite surfaces of a plate. Here the elimination of interference between the sets of

* L. T. Sachtleben, D. J. Parker, G. L. Allee and E. Kornstein, "Image orthicon color television camera optical system," *RCA Rev., 13, No. 1:* Mar. 1952.

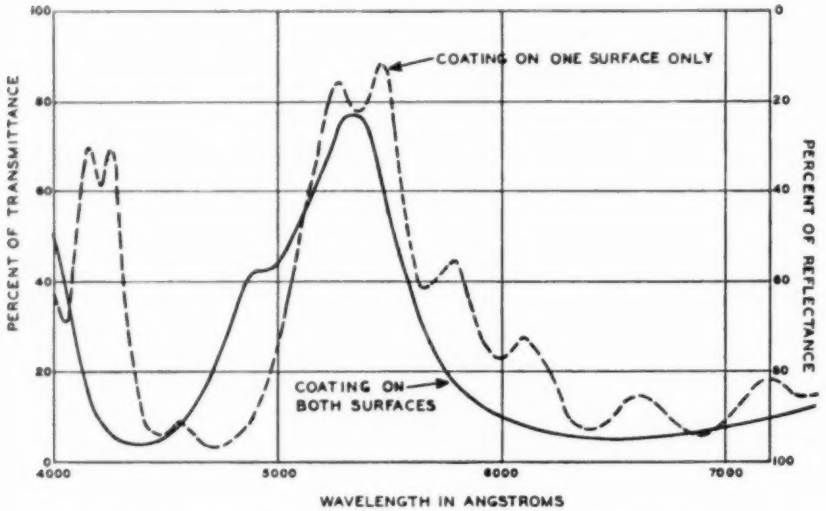

Fig. 9. Light-dividing characteristics obtained by depositing two sets of dichroic films.

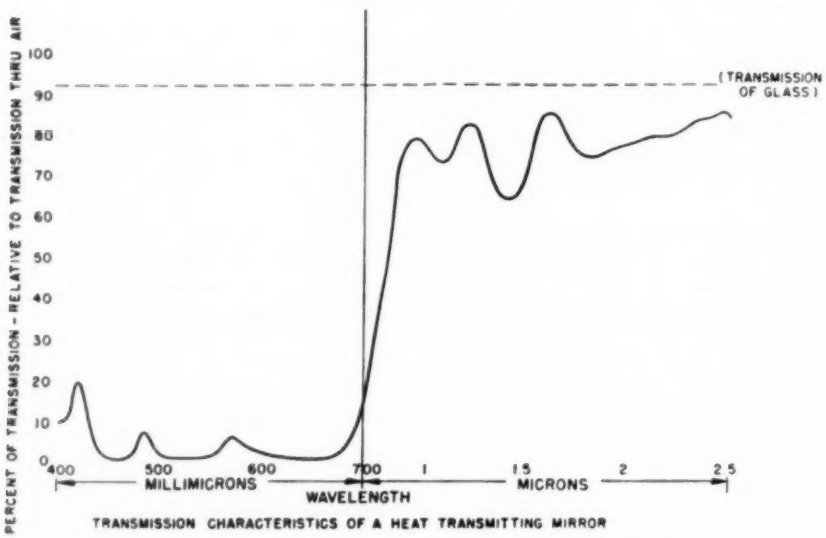

Fig. 10. Transmission characteristics of a heat-transmitting mirror.

layers is more nearly complete. Highly reflecting films can be applied to both surfaces of a glass plate advantageously in many cases; however, this scheme cannot be used in any case where double images are undesirable.

Transmission characteristics for an interference mirror which reflects efficiently through the visible spectrum and efficiently transmits infrared radiation are shown in Fig. 10.* In this case, several sets of layers controlled for maximum reflection at different positions in the visible range, are deposited on one surface of a plate. In this case, no attempt is made to prevent interference between the sets of layers. Interference between the sets of layers improves the efficiency of the film.

Interference mirrors can be made which reflect all wavelengths of the visible spectrum with approximately equal intensity. Such mirrors can be made to reflect as much as 45% of the incident light. A relatively thin layer of low-index material is first deposited on the glass surface, followed by a thicker layer of a material with a high index of refraction. The interference effects of such a film design cause all wavelengths of the visible spectrum to be reflected with approximately equal intensity because of the relative thickness of the component layers for each wavelength. The reflectivity of such a film is plotted with respect to the film thickness in Fig. 11.

The low-index film is slightly less than $\frac{1}{4}$-wavelength thick for blue light. The high-index material is deposited until a reflection maximum is passed and the reflection drops to about 85% of the maximum. Since the low-index layer is not $\frac{1}{4}$-wavelength thick at the point of maximum reflectance, the interfering rays are not exactly in phase. This maximum is, therefore, not as high as it would have been if the low-index film had been $\frac{1}{4}$-wavelength thick.

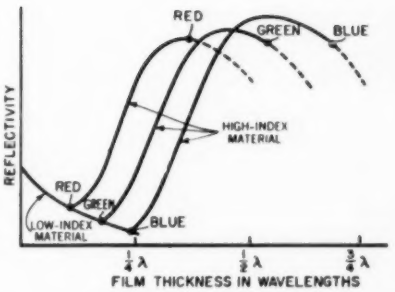

Fig. 11. Design of an achromatic film.

For longer-wavelength green light, the effective thickness of the low-index film is less than for the blue light. The maximum intensity obtainable for this wavelength is, therefore, less than it was for blue. For these film thicknesses then, the reflected intensity for green light has just passed its maximum point, and is approximately equal to the intensity for the blue. And for the red light, having the longest wavelength, the interferring rays are at a point of maximum reinforcement, but the resultant intensity is equal to that of the green and blue. The transmission characteristics of a mirror of this type are shown in Fig. 12.

Discussion

A. V. Loughren, Chairman of the Session (Hazeltine Corp.): The importance of these dichroic mirrors in the development work, which has been going on recently both at RCA and many other places in color television, is something to which I can certainly testify personally. Our own developments at Hazeltine came along far faster than they would have otherwise because it was possible to make arrangements to get some of the dichroic mirrors designed by Miss Widdop and use them in our own work. I have no doubt myself as to their importance.

L. L. Ryder (Paramount Pictures Corp.): Is any work being done in conjunction with these mirrors for high-intensity light levels, for instance where they're used in conjunction with arcs and similar light sources?

* G. L. Dimmick and M. E. Widdop, "Heat transmitting mirror," *Jour. SMPTE, 58:* Jan. 1952.

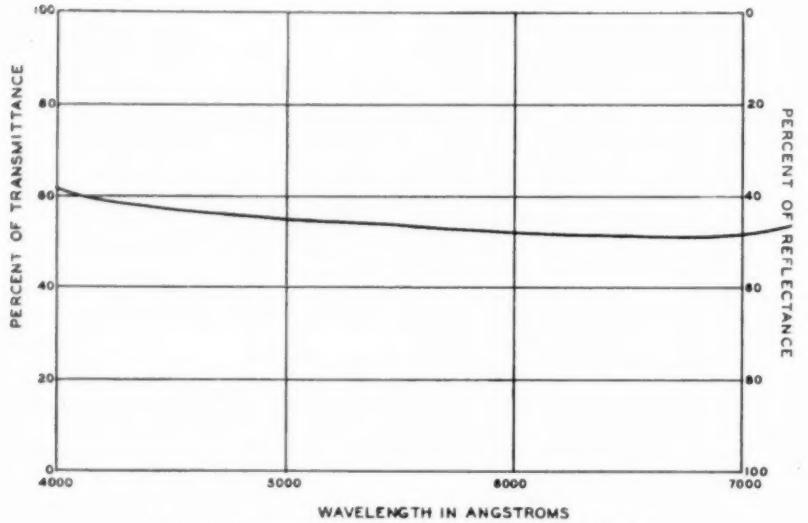

Fig. 12. Characteristics of an achromatic light divider.

Miss Widdop: Well, the heat-transmitting mirror which was the last design shown, was developed primarily with that idea in mind, that it would efficiently reflect the visible light and transmit heat, but it never has actually been applied to that purpose.

Mr. Ryder: The real question is will the coating material stand up against these extreme heats of the arc?

Miss Widdop: We don't feel that the films could be used as front surface mirrors. If they were on the back of the mirror or if they were protected, the heat would not bother them, as far as our experience has shown. We haven't actually had such a mirror in use for a long period of time in a high-intensity arc, but we have made tests with it when it has been in a number of hours. I realize this wouldn't compare with the number of hours a mirror would be used in practice. The difficulty with putting such a coating on the back surface of a curved mirror is that it has to be very uniform or a pronounced color will be reflected. But the coating could be put on the inside surface and another glass put in front to protect it. Or a projector could be redesigned so that the beam is reflected at an angle from a flat mirror and then through the film.

Mr. Ryder: A question pertaining to the resolving power of lenses or lens systems which have the dichroic mirrors: How do lens systems using dichroic mirrors compare with lens systems with no reflection mirror? My interest is lens systems for motion picture or television cameras.

Miss Widdop: I'm not sure that I can answer that question. The glass on which the films are deposited has to be very flat, and compensating plates are used to correct for astigmatism introduced by the thickness of the glass and the angle of the mirrors. The films themselves do not introduce any distortion.

Ralph Heacock (RCA Victor Div., Camden, N.J.): In answer to Mr. Ryder's comment on heat-reflecting mirrors from a practical field viewpoint, we made use of some heat-reflecting mirrors and found that they would not satisfactorily stand up in the field under high-intensity arc light projection. More recently, however, we find with the heat-reflecting, inclined mirror, that if a draft of cool air is directed over the reflector, it operates satisfactorily over long periods of time. The maximum amperage that they have used them under, as far as I know, has been about 105 amp with a 10-mm positive carbon.

ABSTRACT

Television Recording

By W. D. KEMP

Various means of recording vision-frequency signals are considered. For high-definition television, photographic recording appears to be the only practicable method. The film may be moved at constant velocity or intermittently, and some known systems are classified under these headings and described with their advantages and disadvantages, particular attention being given to the two methods now in use by the B.B.C. Various factors affecting the performance of television-recording cameras are then discussed, such as picture joins, interlacing, loss of definition on movement, optical efficiency, film stability, emulsion pile-up, and spot-position modulation. A suitable arrangement of the vision-frequency equipment is dealt with, and the necessary electrical corrections are described. The factors governing the choice of a cathode-ray tube for recording purposes are discussed, while some possible improvements are indicated. The various transfer characteristics concerned have been measured. Contrast correction is discussed, together with possible ways of improving the overall performance, such as high-gamma recording. The conditions for making satisfactory positive prints direct from negative television pictures are stated. Some conclusions based on operating experience of continuous and intermittent systems are then given.

(1) INTRODUCTION

Still photographs of high-definition pictures are readily made, but photographing such pictures on motion picture film in a form suitable for retransmission presents some difficulty. A number of methods have, however, been suggested and some of these are being used successfully.

In Britain, initial development was concentrated on 35mm equipment, but a 16mm system has now been developed. The B.B.C. consider the development of high-quality recording systems on both 16mm and 35mm equipment to be of prime importance owing to the possibility of interchange of programmes with other countries.

Abstract by Pierre Mertz of a paper first presented on November 26, 1951, and in revised form on March 11, 1952, at the Convention on the British Contribution to Television, April 28 – May 3, 1952, by W. D. Kemp, High-Definition Films Limited, 98 Highbury New Park, London N. 5, England. This abstract is published through the cooperation of The Institution of Electrical Engineers, Savoy Place, London W.C. 2.

This abstract is comprised of about 75% of the original paper. All illustrations except Fig. 8 have been retained.

*(3) SYSTEMS OF TELEVISION RECORDING

These can be divided into two groups: those in which the film moves continuously, and those in which the film moves intermittently as in normal motion picture practice.

(3.1) Continuous-Motion Types

To record interlaced television by this method, the geometrical displacement error over the extremes of movement must be less than one picture element, in both line and frame directions.

(*3.1.1*) *Cameras Employing Picture Movement:* In this system, the television picture on the cathode-ray-tube face is moved physically in such a direction that it remains stationary relative to the film, which is moving continuously at 25 frames/sec. The movement of the picture is achieved by electrical deflection of the raster. The high degree of precision to be attained has precluded the development of a practical television-recording system using this principle.

(*3.1.2*) *Cameras Employing a Picture of Special Aspect Ratio and Double Optical System:* This is the normal method of transmitting film by means of the flying-spot principle, but used in reverse. The film moves continuously at 25 frames/sec and two images of the television picture, which is of approximately twice the normal aspect ratio, i.e. 8:3, are focused on the film, separated by half a film-frame pitch. The film moves half a frame pitch during the recording of the first field and this movement restores the aspect ratio on the film to the normal value. During this period the second image is obscured by a shutter. The shutter then obscures the first image and allows the second image to be exposed to the film, the lines falling between those of the first field, since the film has now moved to the required position.

(*3.1.3*) *Shutterless Cameras Employing Optical Compensation:* There are numerous designs utilizing this principle. Most of them were intended for cinema projection where it was hoped to increase the screen brightness and reduce the flicker content, owing to the elimination of the shutter intervals.

Despite the theoretical advantages of continuous-motion projectors, compared with those having intermittent motion, they have never proved popular in the motion picture industry, probably because of the complexity of the various designs. The Mechau projector, however, enjoyed moderate popularity in Germany and an improved version of this machine has been converted into a recording camera for B.B.C. use. Apart from the Mechau projector, only one other type of optical-compensation projector has been used to any extent; this is the type employing a thick polygonal prism.

The system is extremely simple and involves a minimum of moving parts; for this reason it is the basis of most high-speed cameras, exposure rates of up to 3000 frames/sec being attainable. The difficulty for adaptation to television lies in the accuracy necessary in manufacturing the prism, the large size of the prism required for high definition and the problem of adjustment for film shrinkage. A telecine projector working on this system has, however, been built in the United States, and at least one home projector of similar design has been marketed in Germany.

The Latest B.B.C. 35mm Continuous-Motion Recording System: The first B.B.C. 35mm recording suite went into service in October 1949. The design utilized the

* The section numbers in this abstract are not consecutive. The author's original section numbers have been retained for the sake of consistency in reference to the original paper.—*Ed.*

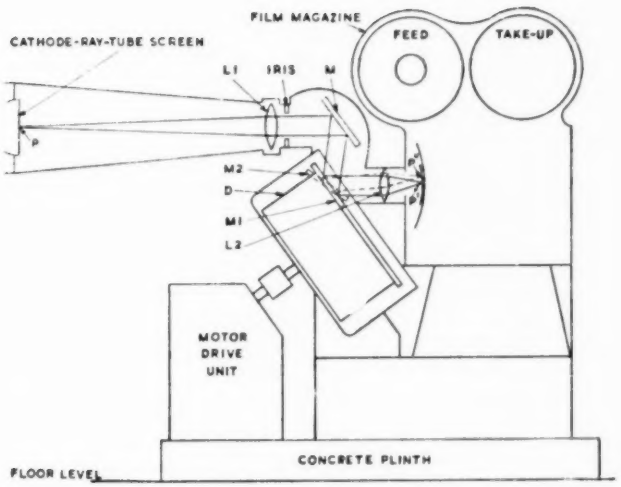

Fig. 1. Schematic of the latest B.B.C. 35mm continuous-motion recording system.

Mechau projector with the original Mechau film-transport mechanism.[3]

Experiments carried out on this equipment showed that the Mechau mirror drum was fully capable of providing correct optical compensation. The film-transport mechanism, however, did not attain the same high standard; it was possible to detect velocity modulation at the sprocket-hole frequency of 100 cycles and at other higher frequencies. This prevented accurate interlacing on the film.

It was therefore decided to redesign the equipment completely, retaining only the mirror and its associated optical system, and three machines of this new type are shortly to be installed at the Lime Grove television studios.

Figure 1 is a schematic arrangement of the equipment. The optical system consists of the collimating lens L1, the fixed mirror M, the mirrors mounted on the mirror drum, M1, M2...M8, and the main lens L2. At the particular position of the mirror drum shown, M1 is producing an image of a point P (on the cathode-ray tube) at P′. As the drum rotates, P′ moves down with the film. When P′ has approached the end of its travel, the cone of light projected by M on to M1 starts to fall on M2, and an image is produced at P″. The distance between P′ and P″ is equal to one film-frame pitch. As the image P′ decreases in intensity, the image P″ increases in intensity, since the luminous flux is shared between P′ and P″.

The exposure sequence is shown in Fig. 2, where (a) represents the television-frame waveform and (b) the exposure produced on consecutive film frames by consecutive mirrors in the original Alexandra Palace equipment. It will be seen that, although the mean exposure period was 0.04 sec, some portion of exposure was received over a period greater than two scans. This resulted in a loss of definition on moving objects in the picture, owing to individual film frames being exposed partially to preceding and following television frames.

When the diameter of the cone of rays falling on the mirrors is smaller than the gaps between the mirrors, the exposure sequence is as shown in Fig. 2(c). There

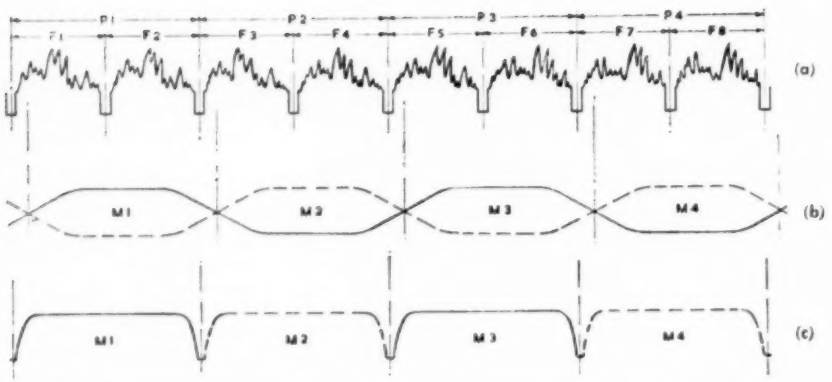

Fig 2. Exposure sequence for the B.B.C. continuous-motion recording system.

(a) Television-frame waveform (F1, F2, etc.—frame period. P1, P2, etc.—complete picture period).
(b) Exposure produced on consecutive film frames by consecutive mirrors in the original B.B.C. equipment (M1, M2, etc.—exposure period).
(c) Exposure sequence when the cone diameter of the rays is less than the gaps between the mirrors.

is now a period when no light falls on the film, and it is therefore necessary to so phase the mirror drum that the mirror change-over period occurs during the television frame-suppression period. A special motor-drive unit provides a very accurate phase lock to the television frame-synchronizing signals. The phase position is indicated by stroboscopic means.

The film-traction mechanism of the original Mechau equipment employed a four-picture sprocket to pull the film through the curved gate. The new film path is shown in Fig. 3. The sprocket S1 withdraws film from the magazine, and, after a free loop, the film passes to a smooth drum D1, which is mounted on the shaft of an eddy-current brake. After travelling through the curved gate G, the film passes round a second smooth drum D2, which has a flywheel of large inertia coupled to it. A small roller R serves to wrap the film round this drum. The film then passes via a sprocket S2 to the sound-recording drum D3 and thence back to S1 and to the magazine. S2 provides the motive force to pull the film through the picture gate. The framing can be varied by rotating R about the centre of D2.

When static, there is no tension in the picture gate. The running tension is supplied entirely by the braking action of D1. The inertia of D2 is so considerable that it would take a long time for the film to accelerate it from rest, and advantage is taken of the lack of gate tension under static conditions by arranging that this flywheel is kept rotating at full speed by means of a separate electric motor. Initially D2 withdraws a small amount of film from the gate, but, as the film is then slack round the drum, no further film can be withdrawn until the main motor of the camera, which drives S1 and S2, is started. Additional contacts on the starting relay then actuate a magnetic clutch which disconnects the electric motor from D2 so that D2 is driven by the film alone.

The film is held against the gate surface by two curved runners independently spring-loaded. The spring-loading is kept to an absolute minimum to avoid gate friction, which is liable to vary and

so produce velocity modulation. The complete gate assembly can be withdrawn for cleaning.

It is hoped that the new film-traction mechanism will produce velocity stability adequate to obtain correct interlacing on the film.

(3.2) Intermittent-Motion Types

(*3.2.1*) *Fast Pull-Down in Frame-Suppression Period:* This is the simplest and most attractive method, but it involves a pull-down and registration period of about 12° on present B.B.C. standards, and, so far as is known, this figure has never been achieved.

(*3.2.2*) *Cameras Employing Two Films:* The proposal has been made to use a double optical system in conjunction with two gates which would have film movements 180° out of phase. The first television picture would be recorded in gate 1, and then, while the film in this gate was being advanced, the next television frame would be recorded in gate 2. Each film, after processing, would have half the television pictures on it, and a step printing process would be required to produce a 25-frames/sec film.

The principal technical disadvantage of any two-film system is the difficulty of ensuring identical processing. Even when the two films are joined together and passed through the same processing machine, variations along the length are difficult to eliminate with the required degree of accuracy.

Obviously, the cost of any two-film system is much higher than that of a single-film system. The time required to produce a finished print is also considerably greater.

(*3.2.3*) *Cameras Involving Memory Systems:* If it were possible to delay every other television field by 0.02 sec, then two consecutive fields could be recorded simultaneously on the film and so the period of one field would be available for pull-down.

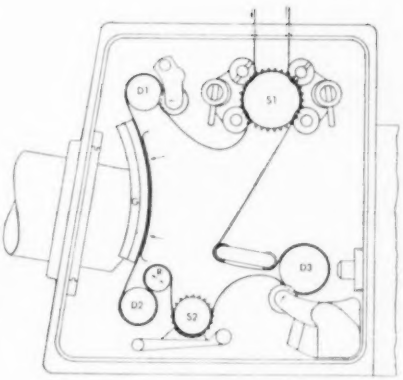

Fig. 3. Film-traction mechanism for the latest B.B.C. 35mm continuous-motion recording system. (M1, M2, etc.—exposure period.)

A suggestion[4] involving the use of a fluorescent screen for retaining the first field has been made. The objection to this method is the characteristic required of the fluorescent material. To avoid frame shading it would have to possess a decay time long enough to allow negligible falling-off in brightness during the time that information was being recorded. At the same time the brightness should have fallen to a negligible value after the next exposure period. The exponential decay characteristic associated with normal phosphors appears unsuitable for this purpose.

There has not yet been a practical development of a camera working on this principle.

(*3.2.4*) *Use of Image Convertor for Change of Standards:* It has been suggested[5] that the television signals to be recorded should be applied to an image convertor which would change the scanning standards and give a greater frame-suppression period to allow an adequate pull-down period of, say, 30° or more.

An image convertor would enable the incoming interlaced picture to be changed

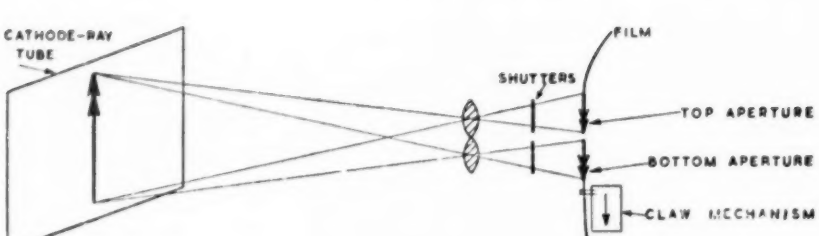

Fig. 4. Schematic of the camera for the Kemp–Duddington system.

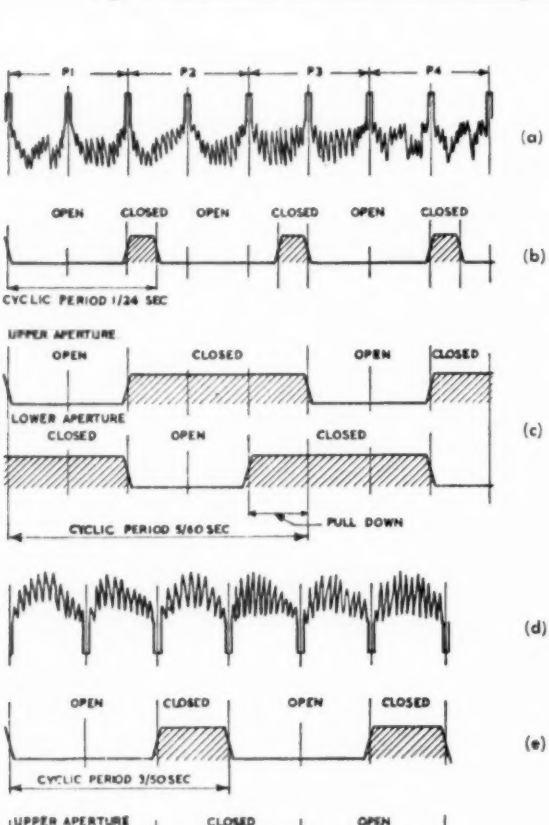

Fig. 5. Waveforms for intermittent-motion systems.

(a) American television waveform (P1, P2, etc.—complete picture period).
(b) Shutter sequence at present used in America.
(c) Alternative American shutter sequence using double optical system.
(d) B.B.C. television waveform.
(e) Exposure sequence for $16\frac{2}{3}$ method.
(f) Exposure sequence for Kemp – Duddington system.

into a sequential picture, which might ease some of the recording problems.

The principal objection to the method is the additional complexity and the distinct possibility of loss of quality in the conversion process.

(*3.2.5*) *American Method:* Although this is not applicable to British standards, since only 24 of the 30 television pictures/sec used in America[6] are recorded, it is interesting to compare the exposure cycle with those of the British methods described in Sec. 3.2.7 and 3.2.8, which are suitable for 25-pictures/sec television recorded at 25 film frames/sec.

Figure 5(a) shows the American television waveform diagrammatically, while Fig. 5(b) shows the shutter sequence at present used in America. It will be seen that every alternate field is joined in the picture area. With the relative phasing of camera and television signals as shown, this join occurs in the centre of the picture; with other conditions of phasing, a join in the picture area occurs on each field. Picture joins are dealt with in Sec. 4.1.

(*3.2.6*) *Alternative Exposure Sequence for American Standards:* This uses a double optical system and double-gate aperture, the images being one above the other. The shutter sequence is shown in Fig. 5(c), and a schematic of the camera in Fig. 4. Television picture 1 is recorded in the bottom aperture, then television picture 2 in the top aperture. One field of television picture 3 is then missed while the film is advanced two frames and the cycle is repeated. The advantage of this arrangement is that there is no picture join.

The method is of particular interest, since the camera developed to record British standards on the Kemp–Duddington system could be adapted to record American standards on the above sequence. A pull-down period of 72° would be required, compared with the 90° on British standards, but it is felt that this could be achieved without radical modification.

(*3.2.7*) *16⅔ Method*[7]: This uses the time of every third scan for pull-down, thus providing 16⅔ film frames for every 25 television pictures. A step printing operation to print every other film frame twice is required to obtain 25 frames/sec on the film. The reproduction of movement is, of course, not so good as in a 25-frames/sec method but should not be worse than that associated with the step printing of 16-frames/sec motion pictures to 24 frames/sec. The exposure sequence is shown in Fig. 5(e), Fig. 5(d) being the B.B.C. television waveform.

(*3.2.8*) *Kemp–Duddington Method*[8]*:* This is the system which the B.B.C decided to develop for 16mm recording.[9] A double optical system and two-frame pull-down is required. The exposure sequence is shown in Fig. 5(f), and the camera schematic is the same as that of Fig. 4.

The first and second scans of television picture 1 are recorded by image 1 in the bottom aperture, and the second scan of picture 1, together with the first scan of picture 2, is recorded on the second film frame in the top aperture. The second scan of television picture 2 is not recorded, the film being advanced by two film frames in this period. The cycle is then repeated. With the phasing shown, no picture join is necessary. To ensure that the correct phasing is maintained, the camera is phase-locked to the television-frame pulses and the relative phase angle is indicated by stroboscopic means.

It will be seen that some 90° of the cycle are available for film pull-down, and in the design of the camera an accelerated triangular cam-movement was used giving a pull-down of 60°, with 15° allowed for registration. This was done by means of register pins fixed to the aperture plate.

Optical registration of the images is necessary, and means are provided for

achieving this to a high degree of accuracy. It is also necessary, although not difficult, to balance very exactly the exposure produced in each gate aperture so that 12.5-cycle flicker is avoided.

The reproduction of movement is theoretically worse than with an ideal 25-frame television-recording system. However, tests have shown that, in fact, movement is reproduced very satisfactorily and compares with normal motion pictures.

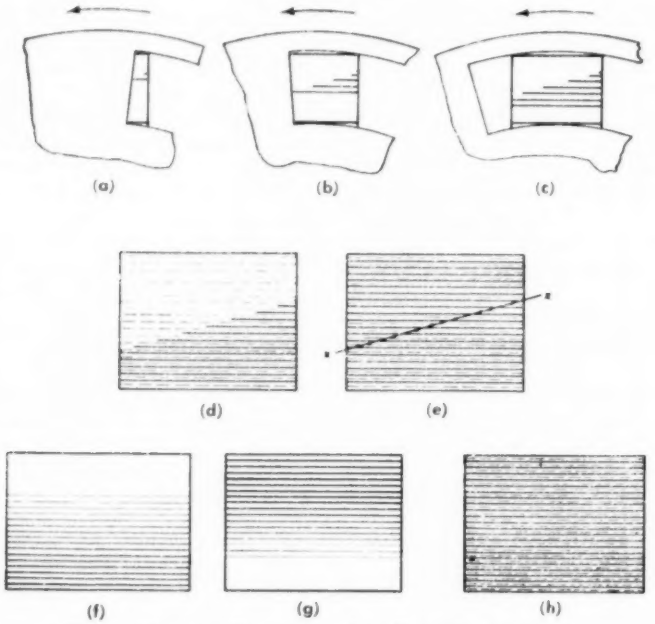

Fig. 6. Diagram illustrating the effect of picture joins.

(a), (b) and (c) show the effect of the shutter opening.
(d) shows the lines recorded during the last scan.
(e) shows the picture join obtained.
(f), (g) and (h) illustrate the fading-shutter method.

(4) SOME FACTORS AFFECTING THE PERFORMANCE OF TELEVISION-RECORDING CAMERAS

(4.1) Picture Joins

In the American system of television recording and in the $16\frac{2}{3}$ or Kemp–Duddington systems, when used in a general phase relationship, picture joins occur in the picture area. With a cathode-ray-tube phosphor of negligible afterglow and using a focal-plane shutter, the sequence of operation is shown in Fig. 6. As the shutter opens after the pull-down period, lines should be recorded of increasing length owing to the diminution of the occulting effect of the shutter edge. This is shown in Figs. 6(a), 6(b) and 6(c). For the next scan the shutter is open, and in the last part of the cycle the lines should be recorded of decreasing length and in such a position as exactly to join with those recorded

one picture period previously. Figure 6(d) shows the lines recorded during the last scan, and Fig. 6(e) the picture join obtained. The effect of afterglow is to blur the edges of the join.

It will be appreciated that, to obtain such a perfect join, the shutter angle and velocity stability of the shutter have to be substantially perfect. In the Eastman Kodak television-recording camera for American standards, the shutter is driven by a separate synchronous motor and the shutter edges are stoned down on test to produce an exact shutter angle. Even so, the picture join could be detected on some early American recordings.[10]

Figures 6(f), 6(g) and 6(h) show a proposed solution to this problem by the use of a fading shutter.[8] In this method, the shutter is caused to fade in the lines gradually, instead of occulting them. One picture period later the lines are faded out, the fade-in zone of the picture overlaying the fade-out zone.

An alternative method of achieving a good picture join is to employ blanking of the recording monitor.[11] In this case, the cathode-ray tube is normally biased beyond beam cut-off. When the film is in the gate and ready for exposure, the camera sends a trigger pulse which raises the cathode-ray-tube bias to the correct figure for exactly one picture period (the correct number of lines being counted electrically), after which the cathode-ray tube is again biased back and the film is pulled down. There is no shutter on the camera. With this system, lines recorded just prior to film pull-down are not exposed to the afterglow and tend to be under-exposed. As the joint occurs only on alternate frames, the variation in density tends to cause 12-cycle flicker. The effect can be reduced by reducing the pull-down time and phasing so as to allow additional exposure time after each television frame. The picture joins produced by this system can be undetectable unless movement has occurred during the picture period when there is a discontinuity at the join.

(4.2) Interlacing

In order to record an interlaced picture by means of a continuous-motion process, it is necessary that the film and scanning spot should move in such a fashion that after an interval of 0.04 sec the scanning spot is in the correct position relative to the film within a small percentage of the line pitch. Even with a 405-line picture, this implies a high degree of velocity stability for the film movement. The difficulties of eliminating sprocket-hole velocity modulation (or "flutter") and slow-speed velocity modulation (or "wow") are well known to motion picture sound-recording engineers, but in their case the integrated displacement error over any period of time is relatively unimportant, providing the period is long.

Much work on the stabilization of film velocity for television purposes has been carried out in connection with flying-spot telecine machines, and it is a tribute to the engineers concerned that substantially 50:50 interlacing with a picture float of less than a line pitch has been obtained. It should be noted that it is the error integrated over the 0.04-sec period that is important, and advantage has been taken of this in selecting the rotation speed of the stabilizing flywheel used in the latest B.B.C. continuous-motion recorder already described, where sub-harmonics of 25 cycles were carefully avoided.

Owing to the nature of the film base, the linear dimensions of motion picture film are variable with its age and the humidity and temperature of the storage conditions. With triacetate base, used for noninflammable film, the sprocket-hole pitch of raw stock is usually within 0.1% of the nominal dimensions, a shrinkage having occurred since perforation. This shrinkage may rise to 0.2% or more if some months are allowed to elapse between perforation and use.[12]

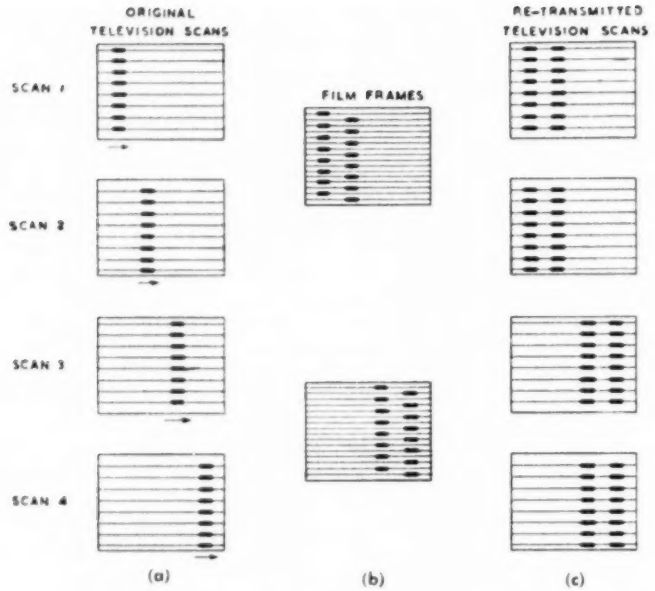

Fig. 7. Diagram illustrating the use of spot-position modulation to eliminate the line structure on recorded film.

Nitrate base, which is inflammable, has the same order of shrinkage initially, but after longer periods of time tends to shrink more than the triacetate base.[13]

In the systems described in Sec. 3.1.3, the linear displacement between the two images must depend on film shrinkage, and in the systems described in Sec. 3.1.1 and 3.1.2, the displacement of the image during the cycle will be required to vary to the same degree. In the present B.B.C. continuous-motion system, the displacement is variable and is set up using a sample of the film stock which will be used for recording. The variations from roll to roll are then small compared to the television line pitch, which is approximately 0.25% of the picture height. This is true, however, only when very careful check is kept on the stock used, and the dependence of interlacing on film dimensions must be reckoned to be a disadvantage of continuous-motion recording.

Intermittent-recording methods do not suffer from the above difficulties since the film is stationary during the exposure period and tolerances in perforation pitch are taken up in the film-advancement mechanism. This is the main reason for the choice of intermittent motion for B.B.C. 16mm recording, where difficulties are increased by the higher magnification.

A further problem of recording interlaced television is the possibility of physical movement between the two scans due to vibration. Vibration frequencies of 25 cycles (or 25-cycle harmonics) are particularly objectionable, as already explained, and long-focus lenses increase the difficulty, since a small angular vibration will then produce a bigger linear displacement.

The difficulties of obtaining interlacing on the film are illustrated by the very high percentage of still photographs

taken of interlaced television pictures which show $188\frac{1}{2}$-line structure.

(4.3) Loss of Definition on Movement

A television programme derived from a live scene provides 50 images/sec of the subject, but two of these are recorded on each film frame, since the film runs at 25 frames/sec. When the film is retransmitted, it is unlikely that the two scans will be reproduced in the correct order. In practice, owing to imperfect frame-deflection linearity, portions of both scans are transmitted in different zones of the picture height. The use of spot-position modulation (see Sec. 4.7) to eliminate the line structure on the recorded film makes it even more difficult to separate the scans. This is illustrated in Fig. 7. Four consecutive television scans of a subject consisting of a vertical line moving horizontally at a rapid rate are shown in column (a). Television scans 1 and 2 are recorded on film frame 1, and scans 3 and 4 on film frame 2, shown in column (b). Column (c) represents the retransmission of the recording when spot modulation is used. It will be seen that a doubling of the image has occurred. When the rate of movement is less than that shown an irregularity on vertical edges is produced.

The doubling of images on fast movement is more objectionable to the eye than the blurring produced by the normal motion picture camera. With television cameras involving storage, however, the doubling is not so apparent since the original images do not have distinct edges.

(4.4) Optical Efficiency and Resolution

Optically compensated continuous-motion systems require a movement of the image during exposure, and this necessitates a greater coverage for the lens. To keep the image in focus during its travel, the film is usually moved round a curved path, the lens being designed to have a spherically curved field, of radius equal to that of the gate. A second cylindrical lens is usually necessary to flatten the field in a plane transverse to the direction of movement.

The above considerations do not make for high resolution, particularly as the use of mirrors often necessitates additional lenses to collimate the light and so prevent double images. It is difficult to obtain a high aperture with such systems. The B.B.C. continuous-motion system described gives an effective aperture of about $f/3.0$.

The Kemp–Duddington 16mm camera has the merit of using the same lens for both images. The effective aperture is about $f/3.3$. The resolution is quite satisfactory; it is possible to photograph an optical test pattern of 1000 picture elements per picture height with good depth of modulation.

(4.5) Film Stability

The defect known as picture float has been referred to in Sec. 4.2, and a continuous-motion film-traction mechanism has been described (see Sec. 3.1.3). It has been found possible to reduce this to small proportions, although it is always present to some extent in continuous-motion recordings. More rapid variations of picture position, known as "jump" or "bounce," are due to lack of registration of one or more film frames with the sprocket holes. Picture jump can occur, for instance, in the mirror-drum type of recorder when one or more mirrors are incorrectly set, or in intermittent recorders when each film frame is not properly registered.

Correct registration is of paramount importance, and it is normal film practice to have separate register pins apart from the claw mechanism used to advance the film. The Kemp–Duddington camera follows this procedure, being provided with a lifting gate and registration pins integral with the camera aperture. Very good film stability is obtained by this arrangement. In cameras where the pull-down is fast, such as the Eastman Kodak for American standards

(pull-down period 72°), separate registration pins are not provided and the elimination of jump is a major difficulty.

The position of the film in the focus plane is also liable to vary, particularly in continuous-motion systems, and this gives rise to focus float. The effect is most serious where long-focus lenses are used, owing to the small depth of focus in the image plane. It is found necessary to focus the B.B.C. continuous-motion camera by actually exposing film at various focus settings. This is not required in the intermittent Kemp–Duddington camera, where the film plane is absolutely fixed by the shuttle gate and aperture plate.

Emulsion pile-up is the main cause of focus variations over long periods of time.

(4.6) Emulsion Pile-up

The emulsion on raw stock is quite soft, and during the exposure of a 1000-ft roll of film, small particles are apt to stick to any portion of the gate surface which is rough, or where there is local pressure. Friction and local heating follow, and the particles build up to solid flakes which hold the emulsion surface away from the image plane. Great trouble from this was experienced in the early days of B.B.C. recording. It was completely overcome by obtaining hard chrome-plating on all gate surfaces and oiling the film. The oil used was pure sperm oil, which was applied by means of two small felt pads spring-loaded so that they made contact with the film adjacent to the sprocket holes on the emulsion side, prior to the film entering the gate; the picture area on the film was not oiled. A single drop of oil applied to the felt pads when each reel of film was loaded was found to be sufficient. Sperm oil forms an emulsion with film developer, and, provided the quantities of oil used are very small, no ill effects result.

Intermittent-motion cameras are particularly susceptible to emulsion pile-up, since there is time for the emulsion to stick to the gate surface and the high initial acceleration of the film then detaches particles. In America use has been made of nylon gates which can be finished with a high polish. Another method used is pneumatic holding of the film in the gate aperture so that the normal pressure pad can be dispensed with.[11] The shuttle gate used in the Kemp–Duddington camera is good in this respect as there is no pressure on the film while it is being moved, the film being quite loose in the gate slide.

(4.7) Spot-Position Modulation

Providing the resolution of the film stock used is adequate, a correctly interlaced television recording contains 377 lines in the picture height. When this is retransmitted on the same standards, the second scanning raster will not necessarily fall over the recorded raster, as has been explained in Sec. 4.2. Moreover, for transcription purposes, the second scanning raster may have different standards, so that registration of the two rasters is impossible.

The effect of this lack of registration is to produce patterns of light and shade over the transmitted picture, the dark portions corresponding to the places where the scanning spot is traversing the unexposed spaces between the recorded scanning lines. The patterns may change in a random manner owing to the random nature of the errors, or may be constant if the accuracy of scanning is sufficient. The patterns can be completely eliminated by eliminating the line structure of the image by a technique known as spot wobbling.[14]

This consists of applying a small high-frequency sinusoidal deflection to the electron beam of the recording cathode-ray tube in order to increase the effective height of the scanning spot without increasing its width. The sinusoidal nature of the deflection tends to produce the effect of a double scanning line because of the low velocity at the maximum and minimum limits of deflection and the high velocity in the mean posi-

tion. When the amplitude of the deflection is adjusted to a critical value, the apparent number of lines in the picture is thus doubled. The size of the scanning spot and limiting resolution of the film emulsion and optical system then prevent line structure being recorded.

In America the spot-wobbling technique is not normally applied because the resolving power of the 16mm film, mostly employed, is not adequate to produce a well-defined line structure with 479 lines in the picture height. The more extensive use of 35mm film in America would almost certainly render spot-position modulation necessary.

(5) THE VISION-FREQUENCY EQUIPMENT

(5.1) General Layout

The operational experience obtained on the two experimental recording equipments originally installed at Alexandra Palace led to the conclusion that a recording suite, intended for the continuous recording of programmes, should consist of three channels. This would allow one channel to be in use while the second channel was being loaded ready for change-over, the third channel acting as a spare. In the event of breakdown, it should be possible to have the spare channel in operation within two or three seconds. The three recording monitors should be adjusted and ready for use at all times, and, should a change be made in the operating conditions during a recording, it should occur simultaneously on all three monitors.

At the Lime Grove television studios, the signals to be recorded are passed into a vision channel where the synchronizing signals are first removed. Control of gain, lift, frequency correction and contrast-gradient correction are then applied. The corrected vision signals and separate line- and frame-synchronizing signals are passed to distribution amplifiers which feed the recording picture monitors or display units. The electrical controls for the vision channel are centralized at a control desk, which has built-in picture- and waveform-monitoring facilities. It is possible to observe the incoming picture on a white cathode-ray tube and to compare this with a duplicate of the picture appearing on the recording cathode-ray tubes, provided by the additional display unit No. 4. A spare vision channel is provided.

Before the start of a recording, test waveforms are applied to the vision channel in use and the local amplitude and cathode-ray-tube bias controls on each display unit are adjusted to give the same transfer characteristic. Measurements are made using a multiplier photocell mounted in a probe held in contact with the glass surface of the cathode-ray tube, so that the brightness of a small area of the screen can be taken. A typical test waveform produces a picture of 15 squares, each of a different brightness. Five squares are disposed horizontally and three vertically. The amplitude of the voltage corresponding to each square varies between zero and 100% of peak-white modulation, in linear steps. By measuring the brightness of each square in turn, the picture-monitor transfer characteristic can rapidly be checked and made similar on the four display units.

To facilitate change-overs the camera-motor controls and the sound and vision faders are situated on the control desk.

(5.2) Electrical Correction

The electrical corrections introduced in the vision channel are as follows:

Frequency Correction: To compensate for the loss of fine detail introduced by the camera optics and film, a high-frequency lift is applied in the vision channel. Since the losses can be expressed as an aperture effect, the amplitude of the lift is made approximately equal to the square of the frequency. A typical value of lift would be 9 db at 3 mc.

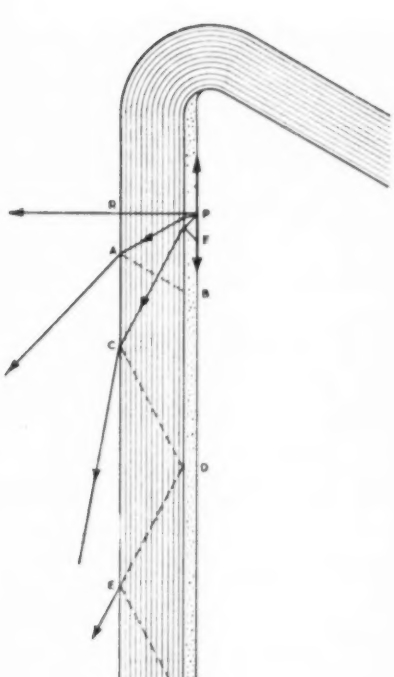

Fig. 8. An enlarged view of the cathode-ray-tube screen.

Phase Correction: This is required because the frequency correction tends to introduce some additional phase distortion, and also to make more apparent phase errors occurring earlier in the chain of equipment preceding the television-recording system.

Contrast Gradient Correction: Owing to the density/log-exposure characteristic of the film it is necessary to overemphasize the tone separation in the highlights and darker tones of the picture to obtain correct tone reproduction on the film. By the use of a nonlinear amplifier, the contrast gradient is increased by a factor of about 2:1 (see Sec. 6).

Lift Correction: For a television picture of full tone range, the difference between the voltage corresponding to the darkest tone in the picture (picture black) and the voltage corresponding to the tip of the synchronizing pulses (black level) is known as the lift. For television signals derived from most cameras, this is varied by a manual control manipulated by the camera operator. The contrast-gradient correction employed renders the vision channel particularly susceptible to changes in lift, and a control is therefore provided to enable minor adjustments to be made.

(5.3) The Display Units

To minimize the loss of quality in a television-recording system, it is essential that the recording monitor should be of the highest attainable standard. Fine focus, maintained over the whole screen even at peak modulation, is particularly important. A substantially perfect interlace is also essential. Freedom from drift in cathode-ray-tube bias and drive over long periods of time is a necessity, since no adjustments to individual display units can be made once a recording has commenced. The geometrical distortion introduced by the recording monitor must also be extremely small.

The vision frequency equipment installed at the Lime Grove studios was built to a B.B.C. specification covering the above points.[15] The response between 10 kc and 3 mc was specified as constant within ± 0.5 db.

(5.4) Cathode-Ray Tubes for Recording Purposes

Film emulsions, even those of the panchromatic type, tend to possess maximum sensitivity at the blue end of the spectrum. This alone would suggest the choice of a blue phosphor such as silver-activated zinc sulfide for the recording cathode-ray tube, and this choice has the following additional advantages:

(a) The phosphor can be made with a very fine grain structure.

(b) The efficiency is high.

(c) The afterglow is short.

(d) The use of a single colour helps optical resolution as the lenses used need not be so accurately colour-corrected.

(e) Screen saturation occurs only at a high brightness level.

Silver-activated zinc sulfide has therefore been used both here and in America for television recording. With recording processes involving relative movement of the film and image, the decay time of the phosphor is more important than colour or efficiency, and zinc-oxide mixtures might be of advantage.

The most suitable size of cathode-ray tube is governed by a number of factors:

(a) The ratio of screen size to scanning-spot size should be a maximum. This discriminates against the smaller cathode-ray tubes, such as those of 5-in. diameter or under.

(b) The brightness should be high. For a given beam current and accelerating potential, the screen brightness is inversely proportional to the area of the raster, which favours the use of a small cathode-ray tube.

(c) Blemishes and grain structure in the phosphor should be negligible. Since these tend to be of constant size, independent of screen diameter, it is desirable to have as large a screen as possible.

(d) The curvature of the cathode-ray-tube face should be slight.

Bearing the above factors in mind a 9-in. cathode-ray tube with an optically flat screen would seem to be a good compromise. This size was ultimately chosen for the display units used in the Lime Grove recording suite. The raster size was 6.7 in. × 5.02 in.

The effect of light reflections in the cathode-ray tube is worth consideration. Reflections may be divided into three types, as follows:

(a) Reflections from glass surfaces other than those of the screen.

(b) Reflections which cause a haze over the whole surface of the screen.

(c) Reflections which cause a halo round a highlight in the picture.

Reflections of type (a) can be eliminated by the use of aluminium backing for the phosphor. This is desirable in any case, since the light output is increased and the danger of ion burn reduced. The crystals of the phosphor emit light in all directions, and the aluminium coating tends to reflect back that portion of the light emitted in the direction away from the recording camera while considerably attenuating any light which may have penetrated the coating and been reflected from glass surfaces behind the screen.

Reflections of types (b) and (c) are less easy to reduce as they are due to the vacuum/glass and air/glass surfaces of the screen itself. Figure 8 (Fig. 9 in the complete paper) shows an enlarged view of the cathode-ray-tube screen. From any point P, rays of light PR, PA and PC are emitted. The portion of the ray entering the glass will again be partially reflected at C and again at D, E and so on. Such rays near the critical angle give reflections of type (b).

Reflections of type (c) arise from rays such as PA, which is partially reflected at A back on to the phosphor at B. The halo is intensified by light travelling from P in the direction of the arrows through the phosphor itself.

A possible way of reducing type (b) and (c) reflections would be to make the glass attenuate the light.

(6) TONE REPRODUCTION

The television camera, and its associated apparatus, converts the light and shade of the original picture into electrical signals of particular amplitude. If these signals are used to modulate a cathode-ray tube, and to expose photographic film, then, when the developed and printed film is transmitted on a telecine machine, the electrical signals produced should exactly correspond in amplitude to the original signals. This would ensure that the tone reproduction

of the television recording would be identical to that of the original and represents an idealized case.

Unfortunately the tone reproduction of the original television camera varies according to the camera tube employed and in most cases is far from perfect. The B.B.C. has in use six types of camera. If correction is applied it should be done in two steps, the first one in the camera chain to obtain better tonal characteristics for direct transmission, and the second step in the recording process to compensate for its deficiencies.

At the present time, owing to signal/noise ratio, absence of black reference level and other considerations, it has not been found possible to correct each type of camera to give a standard transfer characteristic.

(6.1) Transfer Characteristics of Recording Process

Six transfer characteristics are involved as follows:

(a) Amplitude linearity of the electrical equipment associated with the display unit.
(b) Transfer characteristic of the cathode-ray tube used for recording.
(c) Optics of the recording camera.
(d) Overall characteristic of the negative stock and its development.
(e) Grading of the print.
(f) Type of printing stock and its development.

(a) The amplitude linearity of electrical equipment can be made very good indeed. The B.B.C. specification for the Lime Grove 35mm installation specified a limit of $\pm 2\%$ up to 100% modulation and an additional limit of $\pm 5\%$ up to 150% modulation. The contrast-correction amplifier provided however, considerably modifies this response (see Sec. 6.3).

(b) The transfer characteristic of a recording picture monitor may be taken by applying a special test waveform as described in Sec. 5.1, or by applying a number of waveforms in turn, each giving a uniform screen brightness of different value.

(c) The lens system of a recording camera may give rise to multiple reflections from the lens surfaces themselves and from the lens barrel. These produce a haze over the picture which affects the slope of the transfer characteristic, particularly in the dark regions.

(d) The normal density/log-brightness characteristic of the negative stock is somewhat modified by the short exposure period obtained in television recording. Even with a long-afterglow phosphor this is short by photographic standards, and the law of reciprocity breaks down. The effect is to sharpen the toe of the curve, which is an advantage since the straight portion is slightly increased.

The development control gamma of the negative must be such that the overall mean contrast gradient of the recording process is approximately unity.

(e) The grading of the print follows normal motion picture practice, less frequent shot-to-shot grading being required, since this is controlled by the television camera operators.

(f) A standard motion picture technique is used in order to simplify the speed and ease of obtaining copies. The electrical contrast correction in conjunction with the negative development provides a negative of standard characteristics.

(6.2) High-Gamma Recording

The contrast range which can be accommodated in the recording cathode-ray tube is limited by the various reflections which occur (see Sec. 5.4). If the contrast range is reduced by lowering the contrast gradient electrically, then the effect of these reflections is minimized.

In the Lime Grove recording installation the contrast-correction amplifier reduces the electrical contrast gradient to approximately 0.4 over the mid-tone range, and allows an increase of this figure to about 0.8 in the highlights and shadows. The negative control gamma

can then be raised from about 0.7 to over unity, with consequent increase in negative sensitivity.

Additional sensitivity is also obtained from the change of contrast gradient, since if the highlights are kept at the same brightness, any particular tone in the picture will be brighter.

(6.3) Direct Positive Recording

If the vision signals are reversed in polarity before being applied to the recording cathode-ray tube, a negative picture is produced. Unfortunately, however, this picture no longer bears a simple-power-law brightness relation to the original scene.

If a reciprocal law is introduced into the vision chain, the simple-power-law relationship can be re-established and a single photographic process will yield a positive. Provision for this type of recording is made in the Lime Grove installation.

Such "direct positives" have been widely used in the United States, mainly for economic reasons. In most cases, a simple polarity reversal is employed, and the tonal distortion tolerated.

(7) CONCLUSIONS

Since the overall resolution of television on present standards is low compared with optical systems and 35mm motion picture film, it might be thought that the resolution of these items would not be a limiting factor in the overall definition of a television recording. Experience has shown that this is not the case and that it is essential to have first-class optical systems and fine-grain film stock for best results. When 16mm film is used this is even more essential.

Interlaced recording by continuous motion implies a very high degree of velocity stability and usually necessitates complex optical systems. For these reasons it would appear that intermittent-motion methods are more likely to provide the ultimate solution. The development of a suitable quick-pull-down method is therefore of primary importance, since a simple optical system can be used and difficulties due to cathode-ray-tube afterglow do not arise.

There is room for improvement in the cathode-ray tube used for recording. It is felt that existing designs are based largely on normal television-receiver practice, where cost is of primary importance. It may be that by reducing the life of the cathode-ray tube, or some other such factor, considerable improvement could be obtained.

Much work remains to be done on contrast-gradient correction and general photographic technique. Further gains can be expected in this direction in the future.

The recording of television programmes is now a standard operational procedure both here and in America. Since most of the development has been done since the war, this must be considered the youngest branch of television. There seems to be no reason why further development should not yield results of a standard comparable with that of sound recording. If this is so it may be expected that the scale of television recording will be increased to provide a comparable number of programme hours.

For countries starting television systems, it seems that cost will necessitate a large percentage of recorded programmes, and the further development of television-recording technique for the interchange of programmes therefore seems of international importance.

Acknowledgments

The author is indebted to the Chief Engineer of the British Broadcasting Corporation for permission to publish the paper, and to W. H. Cheevers and B. R. Greenhead for help in its preparation. He also wishes to thank others who have

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Synchro-Lite Powered 16mm Projector

By R. E. PUTMAN and E. H. LEDERER

A new flashtube arrangement, providing projection light for television reproduction from film, is here described in detail. It assures accurate and permanent synchronization of light pulse with intermittent pulldown. Further, since both the intermittent movement and the flashing lamp are controlled by the television vertical pulse, the mechanism can readily be interlocked with other picture sources for interpolation, laps and fades. Travel ghost resulting from motion of film while the light pulse is on is made impossible by the design.

MOTION PICTURE film plays a very important part in television stations, both as to programming and as to revenue. The projection equipment used, therefore, deserves the most serious consideration and attention. Methods and devices developed for the very different purpose of projecting a motion picture before an audience are not well adapted to energizing an iconoscope.

The value of pulsed light for film projection in a television system has long been recognized. Among its advantages are very long lamp life, still frame projection without risk of damage to film, accurate control of width of light pulse, high iconoscope output, and freedom from phasing bar in the picture area.

The new Synchro-Lite* Projector to be described here was designed to offer additional advantages. Performance, accessibility and simplicity have been improved. The design permits accurate and permanent synchronization between light pulse and projector action. Drift from synchronization is eliminated. Possibility of travel ghost, resulting from film transit during the interval the light pulse is on, has also been eliminated. Interlock between this projector and other picture sources, including sources remotely located, can be accurately maintained so far as this projector is concerned, since its entire action is controlled by the television vertical pulse.

Mechanism and Lamphouse

The projector mechanism is that described by Fritts† with some relatively minor modifications. One is elimination of the projector shutter, which is not needed, of course. Another is a change in the constants of the coiled spring in the tuned coupling between the

Presented on May 9, 1952, at the Atlantic Coast Section Regional Meeting at Atlanta, Ga., by R. E. Putman, who read the paper, and E. H. Lederer, Broadcast Studio Engineering Section, Electronics Div., General Electric Co., Electronics Park, Syracuse, N. Y. This article is part of a paper presented at the Sixth Annual NARTB Conference, Chicago, April 1952.

* Synchro-Lite is a General Electric trademark.

† Edwin C. Fritts, "A heavy-duty 16mm sound projector," *Jour. SMPTE, 55:* 425–438, Oct. 1950.

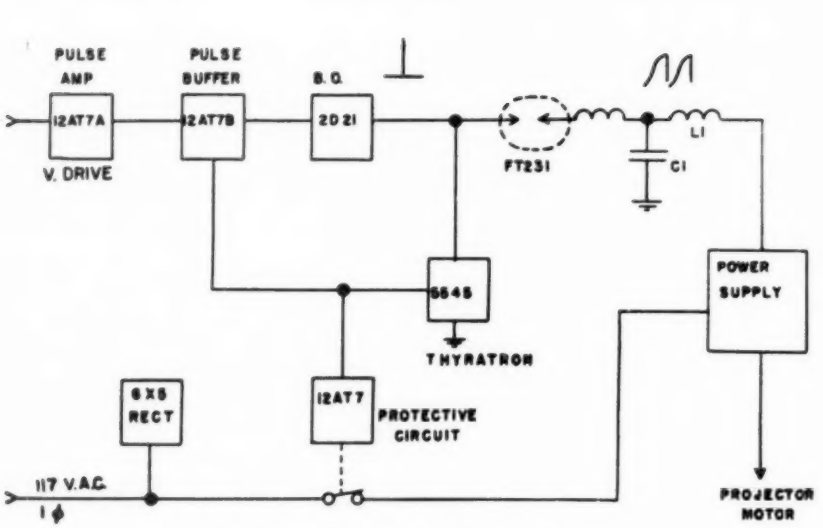


Fig. 1. Circuitry of the Synchro-Lite.

1440-rpm motor and the intermittent movement. This Fritts described as tuned to produce a normal 57° pulldown adjustable to somewhat less than 50° for television. We have adjusted it to 52°. This produces a pulldown time of 6000 μsec, which in turn allows a 9° phasing tolerance based on the maximum vertical blanking time of 8%.

A more drastic departure from the projector as described by Fritts is of course in the lamphouse, where an entirely different light source is used. The housing is cast aluminum with outside adjustments for the height of the flashtube and position of the reflector. The dual aspheric lens condensing system is of the slide type, readily removable for cleaning. This condensing system was specially designed to provide an even and high degree of illumination on the film aperture from the small light source of the tube. The standby projection lamp and provisions for its immediate substitution in case the lamp in operation fails, one of the features of the Fritts design, will not be found in this unit since the flashtube used, GE FT-231, fails gradually after hundreds of hours of use and may be replaced at leisure. Two 5½-in. diameter fans provide forced air cooling for this unit. The power chassis is vibration-insulated from the pedestal to protect the sound system against any iron core vibrations.

Circuit Analysis

Electrical arrangements of the circuit are indicated in block schematic in Fig. 1. The circuitry there shown performs five functions: (1) triggers the flashtube in synchronism with the vertical driving pulse; (2) provides power for the flashtube; (3) controls the width of the resultant light pulse by extinguishing the flashtube after the predetermined interval of 830 μsec; (4) protects the flashtube against damage that might otherwise result from severe noise on the pulse line or other synchronizing generator trouble; and (5) synchronizes the projector motors with the flashtube action.

There are two thyratrons in the circuit: a 2D21 which is part of the trigger; and a 5545 which extinguishes the pulse.

Trigger action begins at the upper left of Fig. 1, where the vertical driving

pulse is amplified and applied to the 2D21 thyratron. This tube can be regarded as a one-kick blocking oscillator. Its plate circuit contains an autotransformer that produces an output pulse 3 μsec wide and 4000 v in amplitude. This pulse of high voltage is used to ionize the gas in the flashtube.

The power supply unit, driven by a standard 117-v a-c line, is composed of selenium rectifiers in a full-wave circuit, delivering 150 v d-c at approximately 2 amp. This d-c output is inadequate for the requirements of the flashtube if used as d-c, but since it is wanted for only 830 μsec it can be readily peaked into an adequate supply. This is accomplished by L1 and C1 of Fig. 1. These two components constitute a resonant circuit of a frequency of 30 cycles/sec. It discharges its energy through the flashtube at a peak current of 70 amp and a peak voltage of 500 a-c, plus the power supply's 150 v d-c.

The thyratron, 5545, is fired simultaneously with the flashtube; and the discharge of C1 completes its circuit through the 5545. L1, however, applies a negative bias to the plate of the 5545 after 830 μsec. The 5545 is thus cut off, and the cycle of events associated with one flash of the flashtube is thereby completed.

The protective circuit of Fig. 1, consisting essentially in the 12AT7 tube, operates through a plate circuit relay to open the line to the selenium rectifier. The tube is normally biassed to cut off; however, if the grid voltage of the 5545 thyratron drifts positive from its nominal value of −17, the 12AT7 conducts and its plate circuit relay is energized.

The filter capacitors of the selenium rectifier circuit provide the 60-cycle a-c used for driving the intermittent motor. The power available is ample for that purpose; and, since the phase of this voltage is dependent on the firing of the flashtube, motor and light are always locked together. In effect, the motor is controlled by a remotely located synchronizing generator. (When a still is projected, an inductance-resistance network is substituted for the motor, providing the same load on the filter as if the motor were running and thus keeping the flashtube current unchanged.) The second harmonic distortion in the filter-capacitor waveform is not of significant amplitude in this operation. Capacity coupling is used between motor and filter.

Results Obtained

The spectrum and the low duty cycle of the flashtube make its output a cold light. A spectral analysis of the output of the FT231 flashtube shows that it has its main peak at about 4600 A. A second peak, which loses its pulsed character, rises in the infrared region, mainly because the electrodes operate at an incandescent temperature. To prevent this infrared light from reaching the iconoscope, a blue-green filter is used.

Curiously, despite the fact that the filter introduces a loss of approximately 20% of the total light energy, there is normally an increase in the signal output from the iconoscope when the filter is introduced. The same result follows if the filter is used with an incandescent lamp. A number of theories have been advanced to explain this phenomenon, but at the moment we do not know of any explanation that is entirely satisfactory. Corning 9780 and 9788 are the two filters in current use.

Comparison of the light output from this projector using the FT231 flashtube with that delivered by a 1000-w incandescent operating through a shutter is difficult to draw because of lack of satisfactory standards. The Joint SMPTE-RTMA Film Equipment Committee, TR4.8, is working toward a solution. They are at present considering, but have not as yet determined upon, a filtered light meter calibrated in Iconoscope Exposure Units. That is, just as foot-candles are measured by a detector having a spectral sensitivity similar to

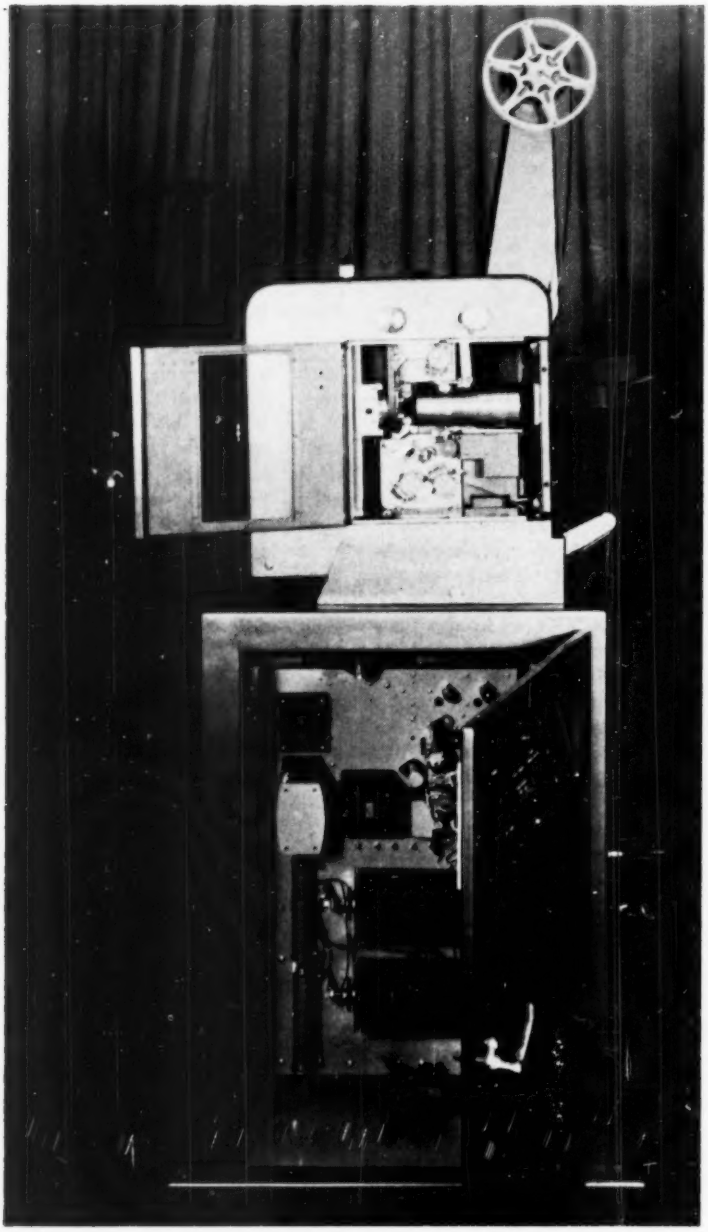


Fig. 2. The complete projector.

that of the human eye, IEU'S would be measured by a detector having a spectral sensitivity similar to that of an 1850-A iconoscope. At 2700 K the foot-candle meter and the IEU meter would give identical readings.

Another way to evaluate the light output of a particular projector is to use a standard television iconoscope camera chain adjusted for optimum pictures, and compare the maximum signal output from this projector with that from a similar mechanism using an incandescent light source. Several checks have been made by this method. They indicate that there is essentially no difference between an FT231 flashtube operating as herein described and a 1000-w incandescent lamp operating at its normal 115 v.

Figure 2 shows the complete projector.

Specifications for the General Electric Projector PF-5-A

PICTURE

Lens: 4-in. focal length, $f/1.5$.
Image distance for $3\frac{3}{8} \times 4\frac{1}{2}$ *image:* 55 in. from aperture.
Resolution of lens: 90 lines/mm over a flat field.
Dynamic resolution: 60 lines/mm or 850 television lines.
Light source: FT231 Flashtube.
Steadiness: 0.15% jump and 0.08% weave.

SOUND

Flutter: less than 0.2% rms.
Equivalent slit width: 0.0003 in.
Signal-to-noise ratio: 55 db, using SMPTE 400-cycle Signal-Level Test Film.
Output: +14 dbm.
Output impedance: 150/600 ohms.
Distortion: 0.5%, 50 to 6000 cycles/sec.

GENERAL

Tilt: ±10% from horizontal.
Power input: 700 w.
Weight: 450 lb.
Size: 26 in. long, 20 in. wide, 57 in. high (less upper reel).

New Professional Television Projector

By W. E. STEWART

A new professional projector specifically designed to meet television needs, which features a high-fidelity sound system with fast stabilization time, is described. A 2-3 pulldown system is incorporated especially for television. All gearing runs in oil and gears and other mechanical parts are designed for long life. Projection lamps change automatically in the event of filament failure. Still pictures can be shown.

WHEN TELEVISION first came on the air, the exact role that film would play in program presentation was not well known. The convenient and simple method for obtaining film programs was to adapt existing projector designs to the job. These projectors have gone through an evolution as they were adapted more and more closely to the special demands of television.

During this same period, we have had the opportunity to see the trend so far as program material is concerned and to confirm the belief that film is an extremely important part of the program. Much of the income for both large and small stations will be derived from programs that go on the air from film.

Operating techniques have also gone through some evolution and are shaking down into a reasonably stable pattern. It appeared appropriate therefore to design a new projector specifically for television, and the new RCA professional television projector, Type TP-6A, for 16mm film is such a machine.

Before starting to design, the opportunity was available to look over general requirements and decide whether the equipment might take some entirely new form. It appeared that the following general objectives should be included:

1. The projector should be a building-block type of item. This means that it should be one able to fit into existing systems and into as many combinations as possible for future systems. It should be separate from optical multiplexing and camera equipment,

2. The main working parts should be at a convenient height for a man standing at the machine, to provide facility in the putting in and taking out of film, and for operation and servicing. In other words, a pedestal is required.

3. The equipment should be adapted to television programming. It should therefore include mechanism for quick and easy threading, and for fast starting and stopping. There should be a minimum of time loss from burned-out lamps and other causes. The projector must be able to show still pictures and be capable of operation by remote control.

Presented on October 6, 1952, at the Society's Convention at Washington, D.C., by W. E. Stewart, Radio Corporation of America, RCA Victor Div., Engineering Products Dept., Camden 2, N.J.

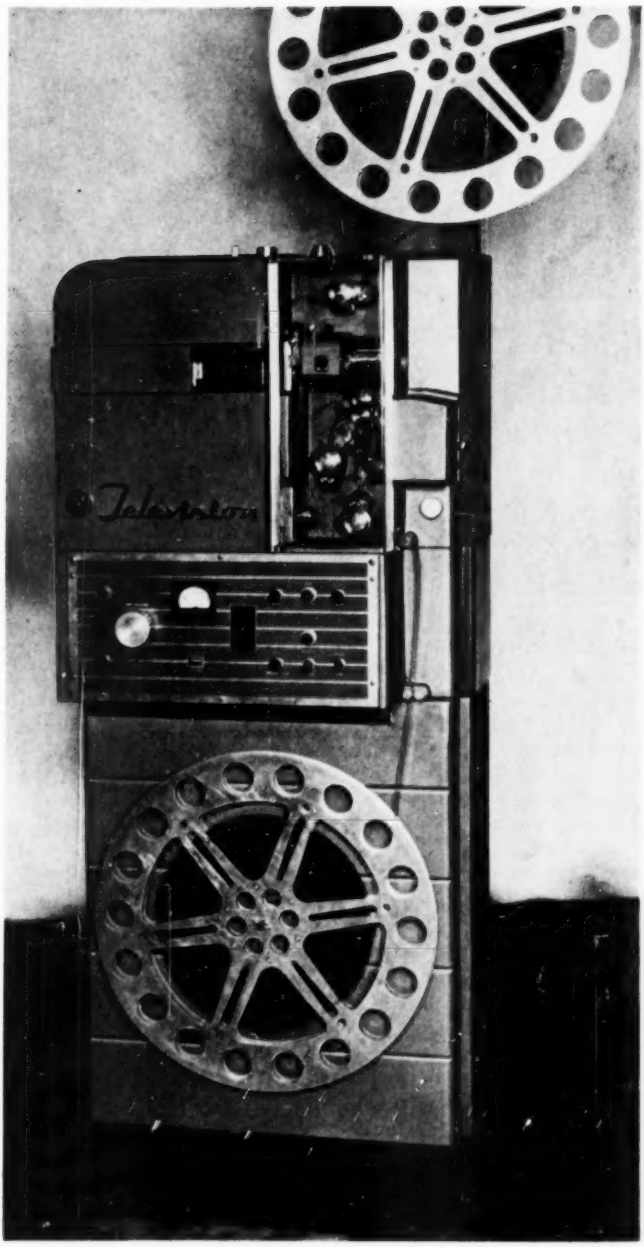


Fig. 1. RCA Type TP-6A television projector.

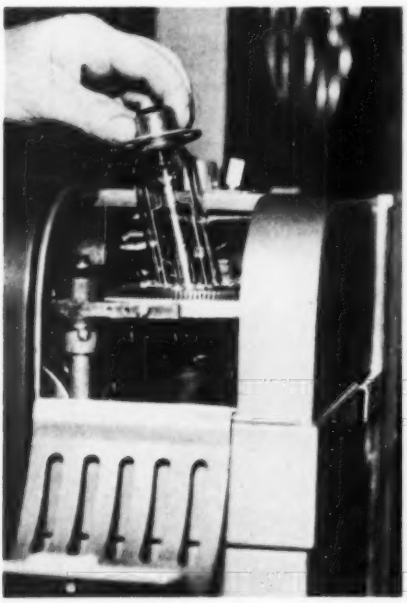


Fig. 2. Automatic projector lamp change mechanism.

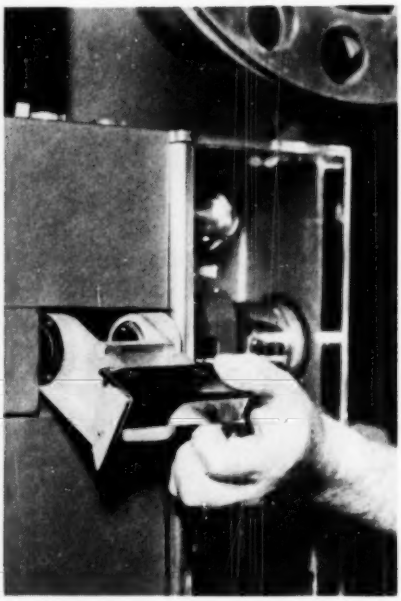


Fig. 3. Removal of lens assembly.

The factors mentioned above are of a comparative nature, and it takes considerable judgment to determine where to put the emphasis. As can be seen from Fig. 1 the machine has a general resemblance to other projectors since it stands on a pedestal and can be serviced from all sides. The extent to which the design engineers stressed various features will become more obvious as details are explained.

Figure 2 shows the automatic projector lamp change mechanism. This mechanism consists of a turret arrangement which holds a 1000-w projector lamp accurately in position until there is a filament failure. The moment the filament current is interrupted, a motor swings the turret around 180° and a new projection lamp is swung into place. This operation requires approximately one second and assures a minimum of interruption to a television program from this common cause of failure. A pilot lamp shows when the bulb has been changed, and the spare can be replaced while the machine is in operation.

A new high-efficiency condenser lens system has been designed for this projector. It includes a filter for taking out the red and infrared light so that a sharper television image results. Removing red also gives a better monochrome picture with color film. The lens assembly is easily removed, as can be seen in Fig. 3.

Two motors are used in the drive system. One handles the shutter while the other drives the sprockets and intermittent. Both are 115-v, single-phase, synchronous motors. These allow still pictures to be shown, an important consideration in television studio techniques.

In order to get as much light as possible on the film camera, a new, fast-projection lens with speed of $f/1.5$ has been designed. This lens, made for the short throw normally found in television ap-

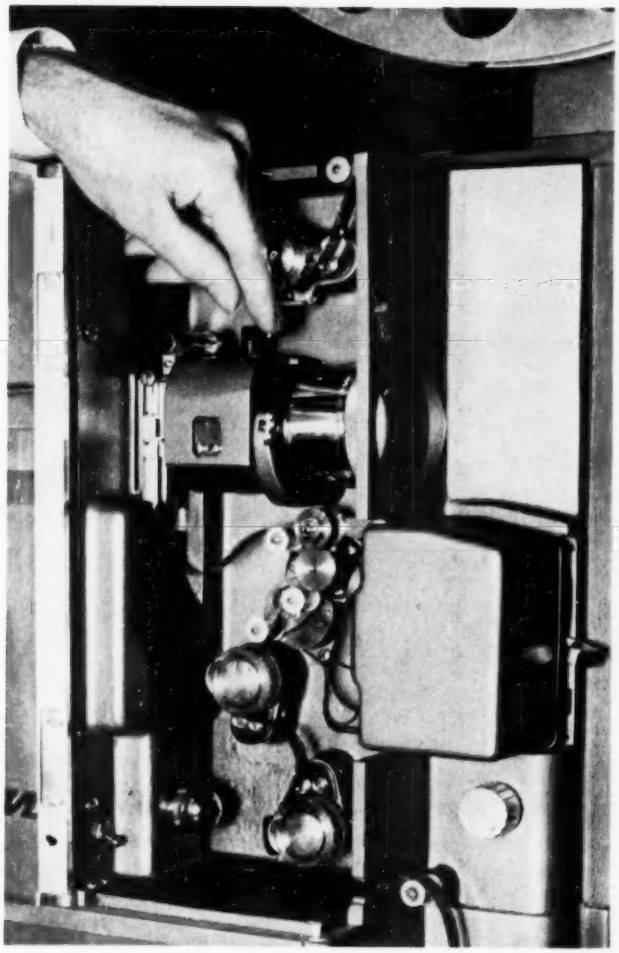


Fig. 4. Interior of projector, showing lens position.

plications, has a focal length of $3\frac{1}{2}$ in. The lens is held in a yoke with a special anti-backlash mounting. Focus controls are available on both the front and back of the projector, so that it is possible to focus the system from either side while looking into the film camera. The projector lens is so mounted that it is not necessary to move it while threading the film, which also insures that it remains in focus. There is a built-in iris in the projector lens. Figure 4 shows this lens just under the pointing finger.

The same figure gives an excellent view of most of the film path. Large or small reels may be used on this projector. A 4000-ft reel which holds enough film for one hour and 50 minutes is shown, but small reels with short commercials on them may be used just

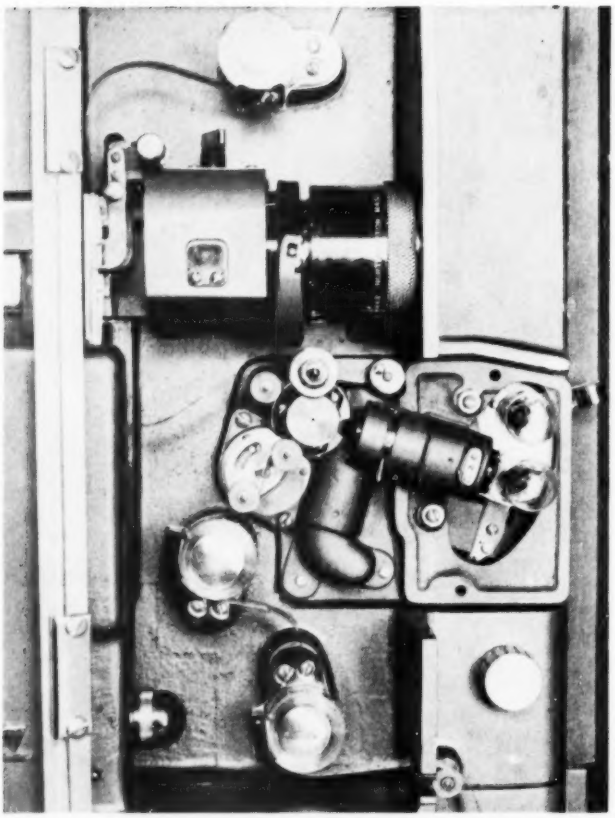


Fig. 5. Path of film through sound system.

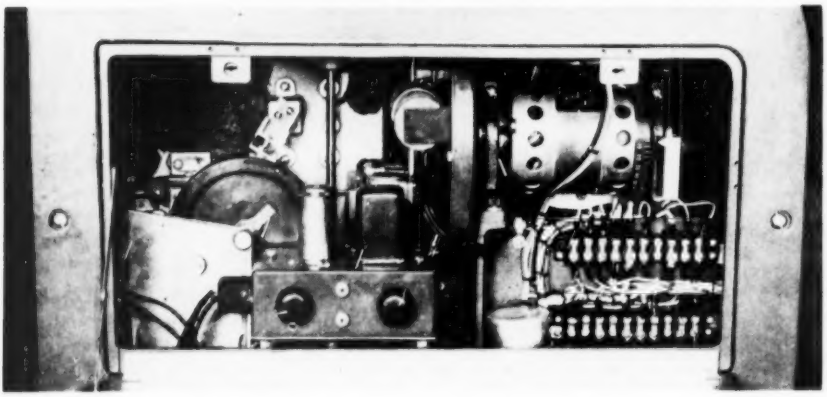


Fig. 6. Interior of projector, showing sound system.

as easily. The supply-reel shaft at the top has a friction brake with a broad noncritical adjustment.

The machine features easy threading. In the figure the finger is shown on a lever which swings the pressure shoe away from the gate so that the film can be slid quickly into place.

There is an adjustment on the pressure shoe so that pressure may be changed while the projector is running, according to the type of film in use. The knob and small calibration dial may be seen directly under the thumb in Fig. 4.

A new sprocket shoe has been developed which can be swung away from the sprocket for cleaning but which will always assume proper alignment and not jam against the sprocket teeth. For threading, the front edge is simply pulled outward while the film is slipped into place.

The sprocket and intermittent mechanism may be turned by a knob at the top to check the threading and to advance the film one frame at a time.

A lamp at the bottom supplies light for threading in darkened projection rooms. The clear plastic door keeps dust from the moving parts but allows constant surveillance of the film.

A great deal of study went into the pulldown mechanism. There is sometimes prejudice against the claw pulldown used here because it has been associated with the simpler and cheaper forms of projectors. Careful analysis of the mechanisms, however, indicates that there is much more opportunity for accurate film indexing in such a simple device, which goes through exactly the same cycle for each frame of the film, than there is in the sprocket pulldown system with its multiple indexing positions for the components of the system in successive frames. A high degree of picture stability has been attained, and should be easy to maintain, in the manufacture and use of this mechanism. It is also important that a lost loop can be restored when using the claw pulldown.

A three-tooth claw is used in this mechanism, so that damaged film will go through it with a minimum of difficulty. The upper tooth and the movable side guides are sapphire-lined. All the gears and other drive mechanism, except the parts which must be outside to move the film, run in oil and are housed in a sealed case. All life tests made indicate that thousands of hours of service can be expected. Complete figures on this are not available, as not one of the mechanisms has yet worn out.

Theatrical-type framing is used for the picture. That is, the position of the film, rather than the aperture, is moved. The framing knob is on top, where it can be reached on either side of the projector — a feature necessary in television.

Figure 5 shows the path of the film through the sound system. The cover has been removed so that both exciter lamps are shown in place. The lamps are 10-v, 5-amp bulbs operated on d-c. They incorporate a new type of internal-heat diffusing screen which greatly reduces darkening with age. A high-efficiency optical system, similar to that in the RCA film sound recorder, gives enough light in the photocell so that the lamp can be operated well below full voltage. These factors tend to give long life to the exciter lamp. In addition, an arrangement is provided that allows a new lamp to be shifted into place immediately by manually operating the lever shown on the extreme right-hand edge of Fig. 5.

The film path for the sound system incorporates several new features. The pressure roller on the sound drum is damped through a viscous drag arrangement to hold the film tight against the drum. After the film passes over the sound drum, it goes through a double-roller system as shown in the figure and this also is damped, so that flutter from the sprocket is effectively removed from the sound-drum motion. Not visible in Fig. 5 is the flywheel on the back end of the sound-drum shaft.

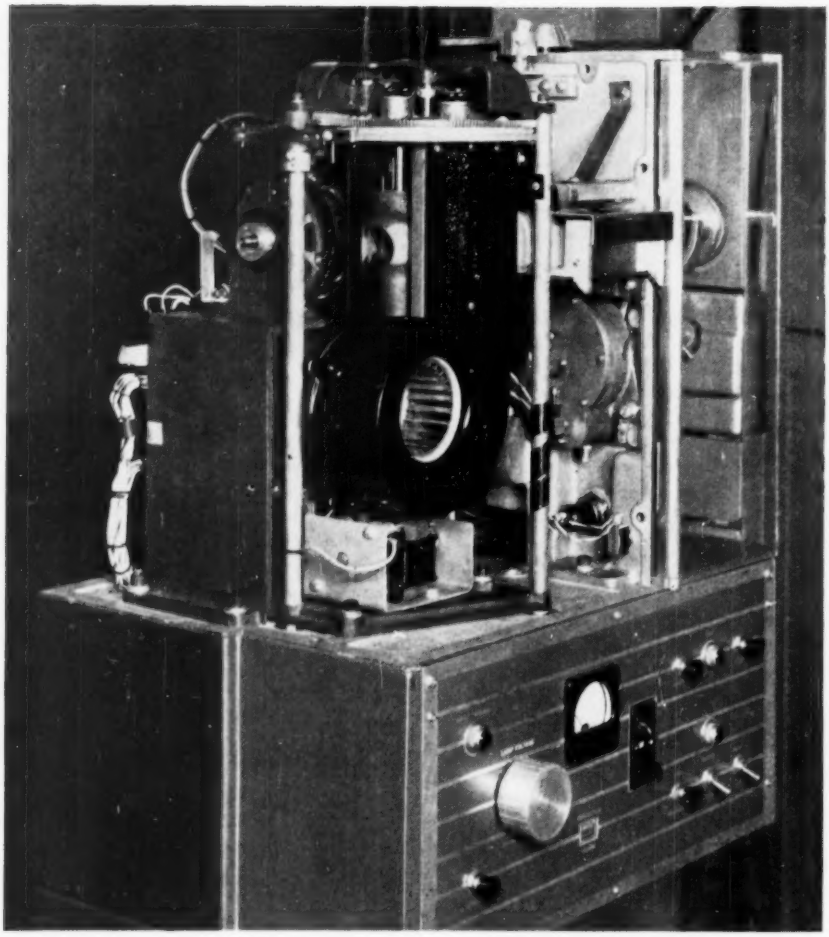


Fig. 7. Control panel.

When the projector stops, a brake shoe is allowed to come against the flywheel, and the film is stopped without being jammed ahead by the inertia of the sound system. When the machine starts, this same brake shoe gives the flywheel a boost so that the whole system comes up to speed rapidly and is stabilized in approximately two seconds. This feature is especially useful in television work where tight programming is involved.

The whole sound system is shock-mounted so that vibration from the projector does not cause microphonics (Fig. 6).

The plug-in amplifier provided with the projector is built with broadcast-quality components and has a response to 10,000 cycles. This response may be limited by a switch to 7000 or 5000 cycles. There is a volume control on the amplifier which allows adjustment of the output level up to 0 dbm. This output is appropriate for connecting to the average

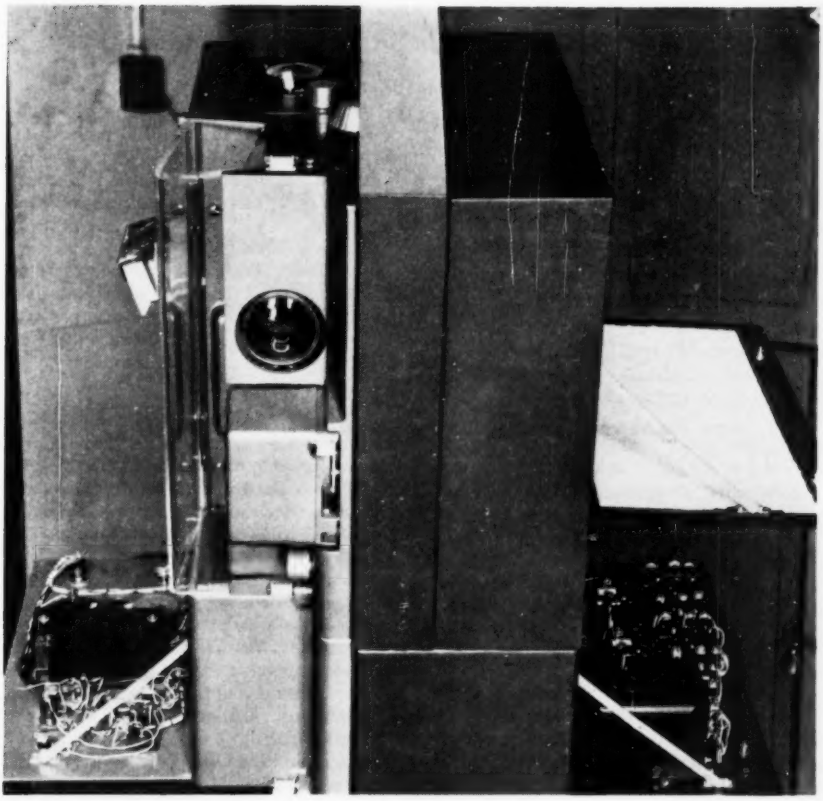


Fig. 8. Top and front view, showing access to control panels and internal mechanism.

consolette circuit and is in line with the new RTMA standards which call for at least −10-dbm output. The standard broadcast audio power supply can be used to supply one or several preamplifiers.

Figure 7 shows the control panel. From left to right the controls and indicators are as follows:

A. The lamp-failure pilot light;
B. Reset button for A;
C. Variac control for projection lamp;
D. Voltmeter for projection lamp;
E. Elapsed time indicator;
F. Main circuit breaker;
G. Start switch (starts the film motion);
H. Still switch starts the shutter motor and places the lamp at full brilliance);
I. Pilot light associated with start switch;
J. "Remote-Local" switch (extends control to the remote control position);
K. Pilot light for this switch;
L. Stop button;
M. Ready switch (activates the control circuits, turns on the blower and preheats the projection lamp).

As can be seen from the same view, servicing has been made easy on this machine. The removal of nine screws allows both covers to be removed from

the projection head. All parts of the projection mechanism are then available for servicing while still in normal operating condition. This figure gives a good view of the blower, lamp-change mechanism, and the intermittent housing.

Figure 8 is a top and front view which shows another kind of access to the projector. The control panels and the internal mechanism are reached by doors with fasteners which can be opened quickly for minor servicing or adjustment.

This view also shows the brake adjustment for the upper reel and the hand turnover knob, framing knob, and changeover knob on the top of the projector.

The main features of the machine are:

automatic projection lamp change;
fast-change exciter lamp;
fast-stabilizing sound system;
4000-ft reels;
still pictures;
long life;
easy maintenance.

Special acknowledgment is in order for the design work of J. J. Hoehn, H. G. Wright and R. N. Lipman who so successfully turned an exacting specification into the machine described. Stewart Pike guided the styling.

Discussion

George Lewin (Signal Corps Photo Center): Can the illumination on this machine be reduced readily for image-orthicon operation?

Mr. Stewart: Yes, there is a shutter in the lens which allows easy reduction in the amount of illumination. Also the Variac controls the projector lamp intensity.

Maxwell A. Kerr (Bureau of Ships): How do you change those projection lamps so quickly without breaking a filament?

Mr. Stewart: Well, if you watch it, you don't have the feeling that it's being jerked around. It's moved around by a motor in quite a smooth motion, but it's about 1 sec of time. There is no particular mechanical jar to it while it's going. It is detented into place so that it is exactly in line and in focus. A microswitch breaks the circuit until the lamp is approximately located.

Mr. Kerr: How fast is that pulldown time?

Mr. Stewart: The cam gives a 90° pulldown at present. We've used faster ones, but this is shorter than our TP35. It's sufficient for the type of application that it is usually used in and will give very long wear of the cam.

Mr. Kerr: That's 90° . . .

Mr. Stewart: The cam with two pulldown faces rotates at 720 rpm or 1 revolution = $1\frac{1}{2}$ sec, which gives 24 pulldowns per sec. Each pulldown section of the cam takes up 45°.

$$\left(\frac{45}{360} \times \frac{1}{12} = \frac{1}{96} \text{ sec}\right)$$

This is the same as 90° of a 1440-rpm cam usually used in projector mechanisms.

Bernie Elias (Film Processing Specialist, Asheville, N.C.): I didn't quite catch just how the pulldown gives more accuracy in the film movement than the sprocket-type movement.

Mr. Stewart: We could spend a lot of time on that, but I'll put it this way. In the sprocket-type pulldown you have usually around eight moving parts which take different positions for each successive position of the film. As a result, extremely tight accuracies are required on those parts with respect to runout and all other dimensional tolerances in order to be sure that the film always stops in exactly the right spot. Here we have a cam which goes through exactly the same cycle for each pulldown of the film. You have only two parts — two mating parts which affect the accuracy of the position of the film; and even if they do vary slightly, it doesn't matter, because they are doing the same thing on every cycle of the pulldown. We have spent a great deal of time on the study of that and we have both systems. The TP35 is the sprocket pulldown. Some of the others are the other way. In answer to the argument that some of the simpler and lower-priced mechanisms use the claw pulldown, you can also say that some of the most expensive equipment in the film recording business uses the claw-type of pulldown also. But we felt, after a very careful study of that subject, that the claw pulldown not only gave us a chance to make a

good machine, but it gave a better chance to have a machine that would work for a long time and maintain that performance.

Eugene Rector (Fox Theatres): On the claw pulldown type, if you lose a loop, sometimes isn't it possible to pick it up again without shutting down, which you couldn't do on your regular intermittent movement. I know you can do that on the 16mm.

Mr. Stewart: Yes, you could restore the loop without rethreading. The machine doesn't have to stop. You can go right on with your projection and restore the loop.

Mr. Rector: You can't do that on the other type movement, on the intermittent type?

Mr. Stewart: No, I believe you cannot. That's right.

Ned Brooke (WSAZ-TV, Huntington, Va.): I'd like to ask is provision made to preheat the filament on the standby lamp?

Mr. Stewart: Yes, during the time that it swings into place. It makes contact almost the instant that the change mechanism starts to operate and is on a reduced voltage of about 25 to 30 volts and then as it swings into place it comes up to full voltage. That gives you a preheating time.

George Lewin (Signal Corps Photo Center): I believe you engage three sprocket holes when you pull down. Does that increase the problem due to shrunk film?

Mr. Stewart: No, in the case of shrunk film I believe the upper sprocket will do most of the work and that's the one that's lined with sapphire. No, that doesn't increase that problem at all.

Anon: Would you tell us what lubricating means is used first on the gear side and secondly on the film side?

Mr. Hoehn (RCA Victor Div.): I can give that: Of course, all the gears are housed in complete-type compartments and are in oil all the time. I am referring to the mechanism.

Anon: And on the film side, how about the rollers?

Mr. Hoehn: All the rollers are nylon, except for the sound drum roller which, of course, is specially damped.

Anon: Does the nylon roller not require lubrication?

Mr. Hoehn: Nylon rollers never need any lubrication. As far as we know, they last longer and have less friction than metal rollers.

High-Speed Photographic Techniques for the Study of the Welding Arc

By I. L. STERN and JOHN H. FOSTER

The use of high-speed photography, at rates of 3000 to 4000 frames/sec, for the investigation of welding arcs is briefly described, with detailed specifications.

IN THE PAST five years, high-speed photography has become increasingly popular as a method for the investigation of the welding arc. Conventional methods of studying the welding arc by electrical metering devices and random observations have not been entirely satisfactory. In many cases the only knowledge of the mechanisms of metal transfer and the factors influencing arc stability have been derived from inferences drawn from electrical measurements. With the advent of high-speed photography, the investigator has been able to observe the actual physical changes in the welding electrode, arc stream and molten weld pool, thereby developing information which can be considered as fact rather than an inference.

Presented on October 9, 1952, at the Society's Convention at Washington, D.C., by I. L. Stern and John H. Foster (who read the paper), Material Laboratory, New York Naval Shipyard, Brooklyn 1, N.Y. The opinions expressed herein are those of the authors and are not to be construed as reflecting the views of the Department of the Navy or the Naval Service at large.

For a better understanding of the problems involved and the high-speed motion pictures (shown at the Convention Session), a brief description of the welding process will be helpful. Essentially, the circuit in which arc welding occurs consists of a power source, an electrode surrounded by a protecting atmosphere, the base metal or object being welded and the arc stream between the base metal and electrode. In some forms of arc welding the added weld metal is derived from a consumable electrode, while in others, a separate filler rod, introduced between electrode and base metal, is the source of the required weld deposit.

The most common type of arc welding is that accomplished with a covered metallic electrode. As the arc is struck, the metal from the electrode is melted by the heat of the arc and transferred through the arc stream to the work or base metal. As the electrode is consumed, the covering is progressively burned or melted off, the latter forming a slag and an atmosphere of gas, which protects the molten metal from atmospheric contamination, and serves as a source of stabilizing ions for the arc.

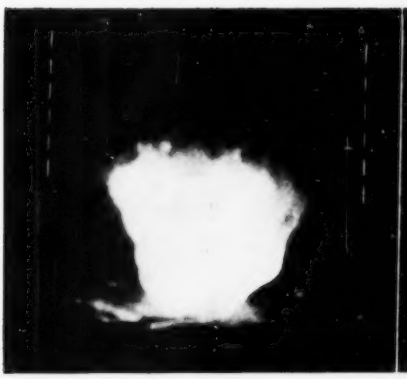


Fig. 1. Metal transfer during short circuit.

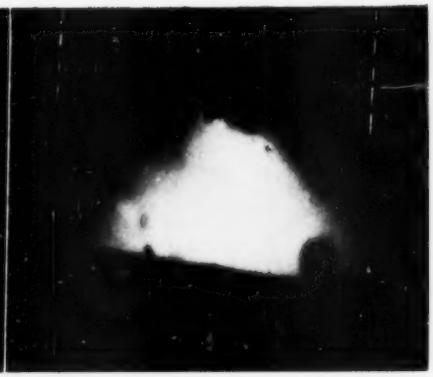


Fig. 2. Explosive burn-off of electrode covering.

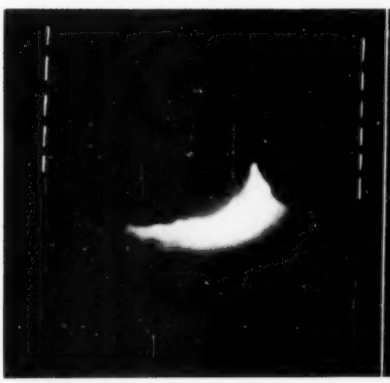


Fig. 3. Flaking and uneven burn-off of electrode covering.

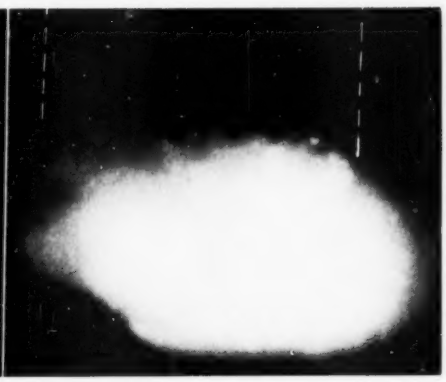


Fig. 4. Passage of slag from melted covering.

The process is accompanied by an intense amount of light and heat. The fumes from the mineral or cellulosic covering envelop the relatively small area of action. These plus the intense light and extremely rapid and varying conditions in the arc complicate the problems of the photographer and the investigator.

For practically all investigations of the welding arc, only close-up views of the largest practicable magnification were found to be of value. High-speed pictures other than close-ups do not appear much different from films taken at normal speeds and do not yield significant information.

In respect to speed required, photographic studies have indicated that pictures taken at 3000 to 4000 frames/sec were satisfactory. Frame-by-frame examination of the films have in some instances indicated that higher rather than lower speeds may be required for some studies. In several cases, the significant changes in the particular fac-

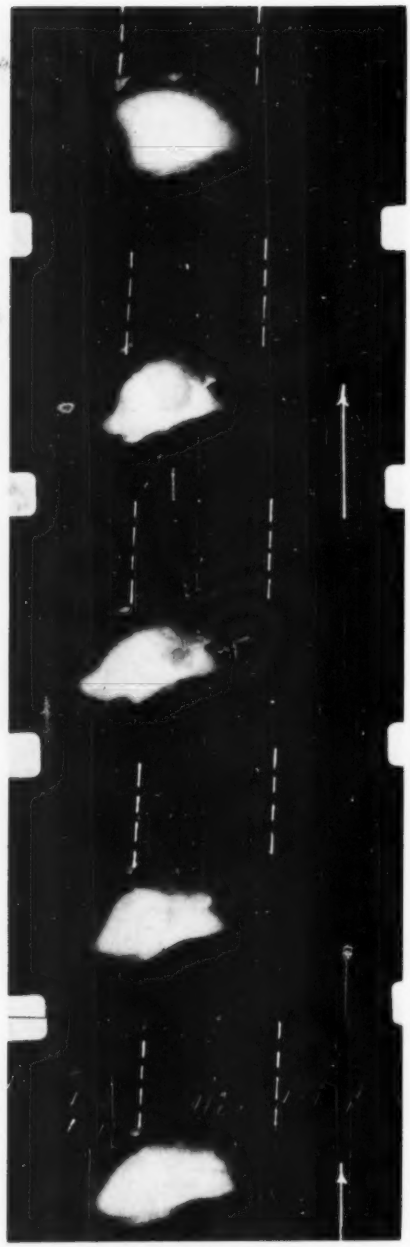


Fig. 5. Transfer occurring within 1/1000 sec.

tor under investigation occur in a time interval represented by 1 or 2 frames. This change would not be evident at normal projection speeds and occurs too rapidly for analysis at 4000 frames/sec. For these special cases, even higher speeds would be desirable.

In most photographic studies it is often necessary to correlate the film frames with recorded electrical measurements such as oscillograms. Most high-speed cameras are or can be equipped with a flashing argon lamp which forms light impressions at the film edges at intervals of 1/120 sec. The corresponding electrical impulse for each flash may be used as a reference timing line on the oscillograph. A preferable system is a newly developed double-lens camera wherein the oscillograph trace and the visual conditions occurring in the welding arc are recorded on a single frame simultaneously.

At the Laboratory with which the authors are associated, high-speed pictures have been taken on black-and-white, infrared and indoor- and outdoor-type color film.

Black-and-white film does not differentiate between the various light frequencies emitted and consequently the resulting pictures are masked by the glare surrounding the arc.

Infrared film tends to overemphasize some aspects of the arc at the expense of others and consequently does not give a true picture of the arc conditions. However, in the case of specialized investigations, this distortion of conditions may prove desirable because of the overemphasis that it produces.

Daylight-type color film is the film of choice for most investigations of the welding arc. Clear, definitive pictures of the metallic arc, tungsten arc and other welding operations have been taken with this film, without the use of filters.

Indoor-type color film may also be used; however, in this case appropriate filters are necessary for optimum results.

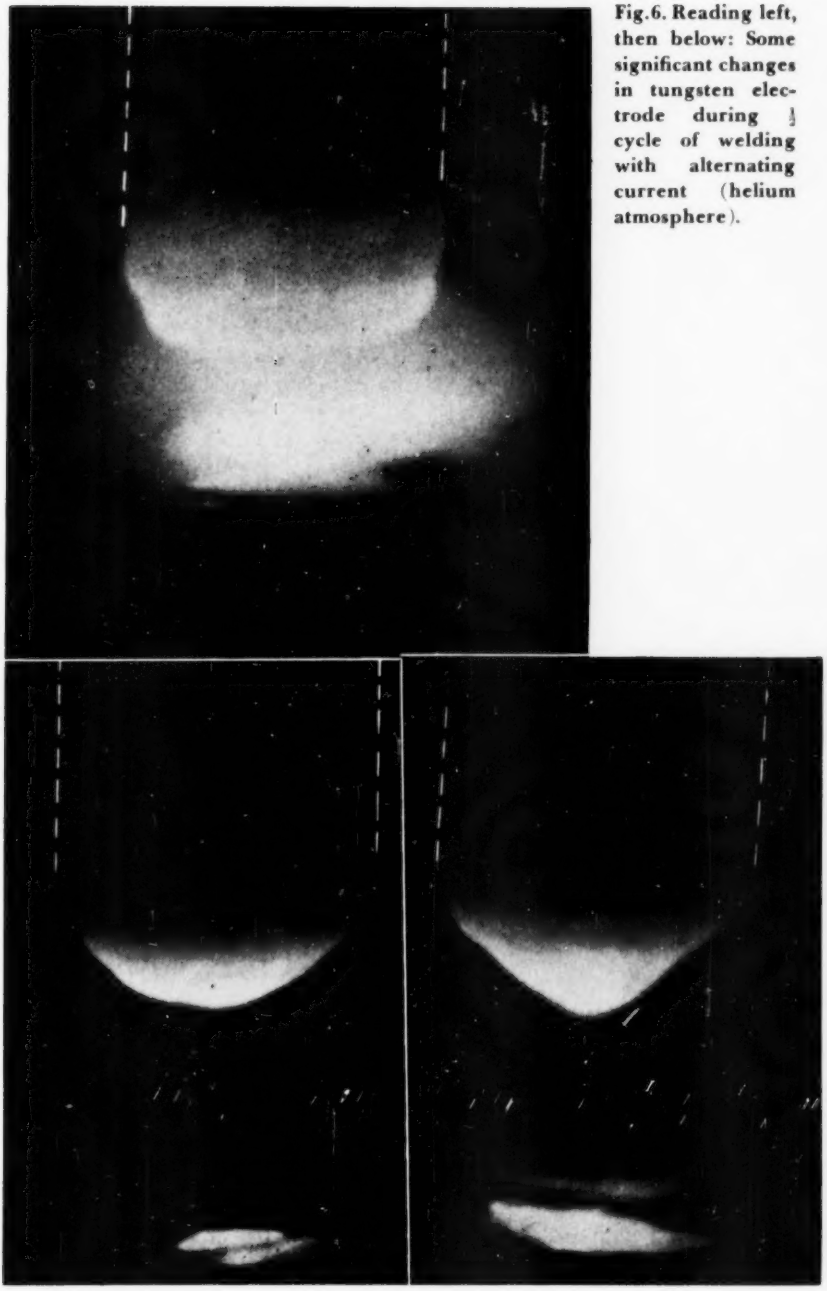


Fig.6. Reading left, then below: Some significant changes in tungsten electrode during $\frac{1}{2}$ cycle of welding with alternating current (helium atmosphere).

For metallic arc welding operations with covered electrodes a Wratten Filter No. 29 is recommended.

The intensity of light emitted by the arc is so great that auxiliary lighting is considered to be of questionable value. Lens openings should be stopped down to $f/22$ or lower to prevent overexposure.

The specifications used for most of the films shown at the Convention were as follows:

Film Speed: 3000–4000 frames/sec
Film: daylight-type, color
Lens System: $f/2.7$, 102-mm lens, plus a supplementary 220-mm lens of 2-in. diam.
Lens Opening: $f/22.0$
Distance of forward element lens to arc: 7 in.
Auxiliary Lighting: 4 RSP2A bulbs
Auxiliary Equipment: $\frac{1}{7}$ hp centrifugal blower with 4-in. duct for removal of fumes when present

A completely automatic procedure, whereby the camera is actuated at a predetermined position of the welding electrode, is a practical necessity for acquiring the desired angulation and view.

Figures 1 to 5 represent single-frame enlargements from the motion picture and illustrate the various aspects of the welding arc which are shown to greater advantage in high-speed motion pictures. For the purposes of clarification, the edges of the welding electrodes have been indicated by dotted lines. Figure 6 illustrates a tungsten-metal arc process of welding with alternating current whereby an inert gas such as helium replaces the covering as a shielding medium. Shown are some of the significant changes that occur within $\frac{1}{2}$ cycle (1/120 sec). The alternate melting and cooling of the tungsten electrode which occur during the reversal of current direction during the cycle is clearly demonstrated.

In general, recent developments indicate that high-speed photographic techniques will play an increasingly valuable role in investigations of the welding arc, and in other fields of technology. The application of procedures similar to those described here should enable the photographer to obtain satisfactory high-speed motion pictures for welding-arc investigations.

The authors wish to acknowledge the cooperation of N. A. Kahn, Head Metallurgist of the Material Laboratory, for his valuable suggestions and for his review of the paper.

Use of Photography in the Underground Explosion Test Program, 1951–1952

By R. M. BLUNT

The Underground Explosion Test Program was established to determine the resistance of soils and structures to attack with high explosives. This paper discusses some of the problems in applying high-speed motion picture photography to the surface phenomena accompanying these tests. Some improvements in equipment and methods were suggested, based on observations made in the field.

The Corps of Engineers, U.S. Army, Sacramento District, established a program to determine the effects of underground explosions in various types of soil and rock and on structures within these media. This program began at Dugway Proving Grounds, Utah, in the spring of 1951 and was completed last summer (1952) in Buckhorn Wash, Utah. Although the primary instrumentation consisted of force gauges of various types mounted on the structures or in the medium, it was thought desirable to supplement the information so obtained with high-speed motion pictures of the charge and its environment. In the spring of 1952, it was decided that high-speed motion pictures of the interior of the structures would provide useful information about the behavior of the walls under stress.

Inasmuch as the characteristics of the medium and the location of the charges in it were of primary importance to the program, the test sites were chosen to satisfy the requirements imposed by these factors. As a result, the terrain often presented considerable difficulty from the standpoint of photography.

The surface of the ground at the charge site was usually below the level of the surrounding terrain; consequently, in order to photograph the surface of the ground above the charge, it was necessary either to elevate the camera or to bulldoze a long, sloping ramp through which the camera could view the charge area. However in many cases even this was not possible when the territory surrounding the charge location consisted of a series of small hills, sand dunes, tree-covered ground or other such natural obstacles. Therefore, in many cases the cameras were not located at the optimum spot but at the best of the few possible locations. The rock sites were particularly poor from the standpoint of camera locations, since there always seemed to be a deep

Presented on October 8, 1952, at the Society's Convention at Washington, D.C., by R. M. Blunt, Denver Research Inst., University of Denver, Denver 10, Colo.

Fig. 1. Terrain typical of that found in the soil sites. This picture, taken from several miles away, under-emphasizes the features which cause trouble in finding a good camera location.

gulley or ravine at precisely the position in which one would prefer to put the camera (Fig. 1). Much of this difficulty might have been overcome by setting the cameras very close to the charge because a fairly level area usually extended for a radius of some 50 ft around the charge location. This probably would have resulted in a loss of cameras, since debris can travel for quite some distance at a very high velocity, particularly from the charges detonated in rock. To reduce the hazard from debris, even when set up at some distance from the charge, the cameras were routinely protected by shelters constructed from 2 × 6 timbers, braced by 2 × 4's and 4 × 4's to withstand the shock of any flying material that might strike them (see Fig. 2). A 3-in. circular aperture was cut in the side of the shelter which faced the charge to permit the camera to see through it. The side of the shelter facing away from the charge was left open to provide easy access to the equipment. The chance of anything striking the small target represented by the aperture or by the lens of the camera was small. We were fortunate in this respect, inasmuch as no camera was damaged by flying debris during the entire program, although there were several near misses.

A difficulty of another type arose from the fact that the charges were primed in such a manner that the detonation of the primacord fuse occurred directly above the area in which we were most interested. The detonation of this primacord always left a large cloud of black smoke which obscured the early portion of the phenomena being photographed, particularly when the charge was a small one. With a larger charge the cloud covered proportionally less of the area of interest.

These difficulties are brought out here to provide information for others who may set up similar programs. It is thought these comments may result in consideration of photographic requirements early enough to make proper provision for them possible.

Lighting conditions existing in desert country in the West are usually fairly good for the purpose of taking high-speed photographs between the hours of 9 A.M. and 3 P.M. Depending

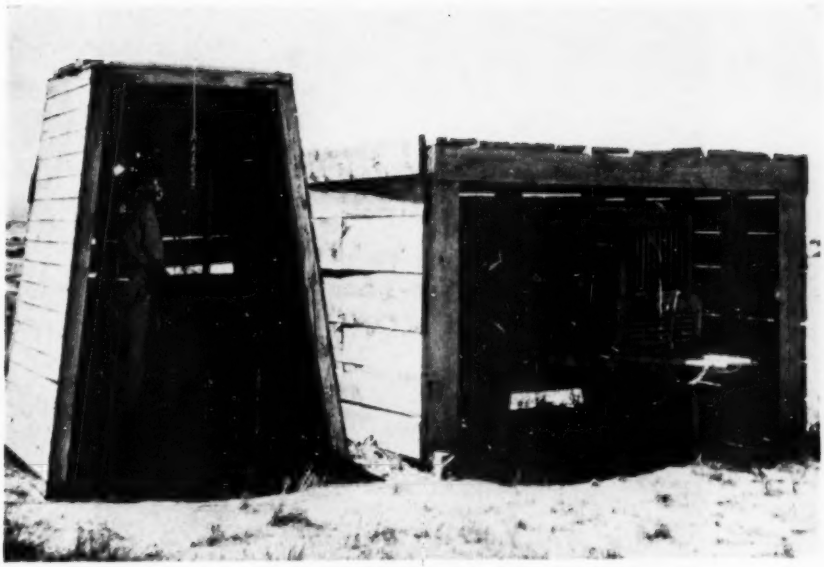


Fig. 2. A rock site installation of camera and power source.

upon the time of the year, one may reasonably expect reflected-light readings on average countryside to be between 800 and 1600 Weston at these hours. With this lighting, quite satisfactory pictures were obtained at frame rates as high as 4000 per second when the background consisted of either a light-colored sand or a light-colored clay. The chief problem that arose was that of obtaining sufficient contrast between the particular part of the ground in which we were interested and the background (see the second picture in the sequence of Fig. 3). In some desperation we finally resorted to the expedient of spreading powdered coal over the surface of the ground immediately behind the object we were photographing. Since the object seen by the camera was of a light color in general this provided a reasonable degree of contrast in the final photograph. Without such precautions it was sometimes extremely difficult to distinguish between the rise of the ground, in the area of interest, and the terrain behind it. When the field to be photographed is rather dark, as, for example, when the ground is covered with sagebrush, it is necessary to reduce the frame rate of the camera to about 2000 frames/sec when the light reading is of the order of 800 Weston if satisfactory pictures are to be obtained.

Due to the requirements of the program, it was necessary to set up the high-speed motion picture cameras a few hours in advance of the expected time of detonation of the charge. This was done to allow the photographic crew time to set up and man other equipment at stations located a mile or more distant from the charge site. It was thus generally impossible to readjust the high-speed motion picture cameras for the light conditions existing at the time of the detonation. Even in the event of considerable changes in the prevailing light, as were occasioned by storms which frequently arose in the late afternoon, we were quite surprised at the quality of the pictures that were

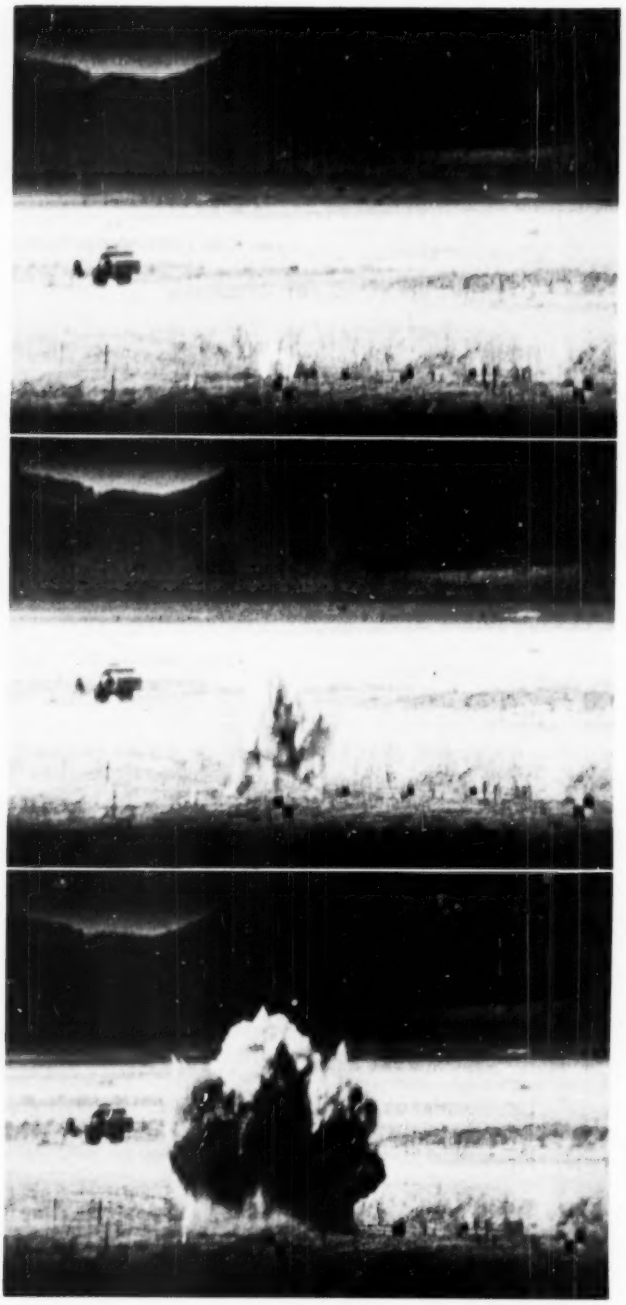


Fig. 3. A sequence taken from the

16mm Fastax picture of a typical test.

taken under these adverse conditions. In one instance in particular the light reading was approximately 50 Weston, the camera was operated at a rate of 1000 frames/sec, and we still secured a picture from which usable information could be had. This should not be construed as recommending that one make a habit of taking pictures under such conditions, but merely to indicate that it can be done.

In general, with phenomena of the type under investigation in this program, it is desirable to set the camera for the maximum possible frame rate obtainable with the light that is available. This is particularly true in rock where the phenomena occur so rapidly that a rate of less than 2000 frames/sec results in pictures which are almost useless from the standpoint of analysis. A rate of 4000 frames/sec is the minimum, and it would be better if one could obtain pictures at rates more closely approximating 8000 frames/sec. However, this does not seem possible at the present, even with the illumination provided by the sun on a bright day in the desert. It would be worthwhile to experiment with various types of artificial light sources to supplement the illumination from sunlight. Some means of providing a fill light to control contrast would make the problem of securing a good high-speed picture much easier. In this connection it may be well to point out that use of Linagraph Pan Film in an attempt to secure a higher frame speed through the greater emulsion speed of this film resulted in quite unsatisfactory pictures. We therefore carried out a short investigation of the suitability of the various types of film that we could readily secure (see Fig. 4). Unfortunately, the halftone reproduction does not convey the differences visible in the original films, particularly with respect to grain.

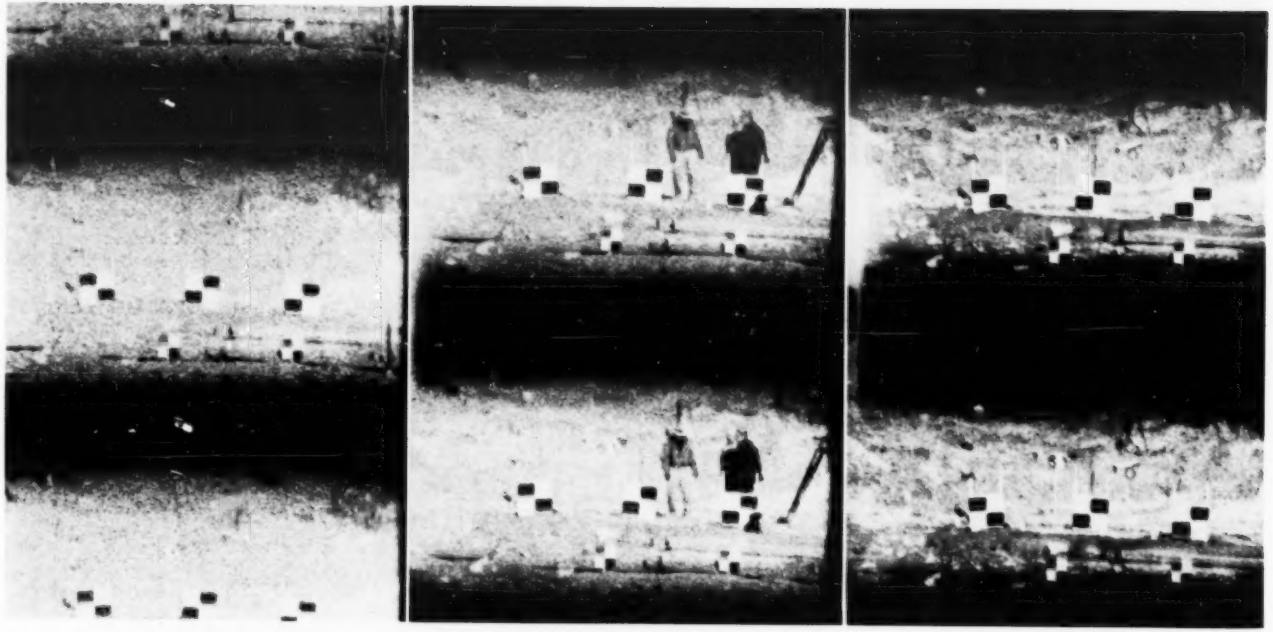
A camera was set up to photograph a typical charge area and several different types of film were run through in the space of some 15 min. During this time the light did not change and the camera settings were left the same. Therefore, to at least a first approximation, the only variable involved was that of the film type. This film was all processed through the Houston machine in D-16 developer at approximately 80°F at about 4 fpm, which would correspond to approximately $7\frac{1}{2}$-min development time. The film found most satisfactory as a result of this test was Ansco Gun Film. The rest, in order of decreasing merit, were: Background X, Linagraph Shellburst, Linagraph Ortho, Super XX, and Linagraph Pan. Of course, one is never satisfied, and it would still be desirable to have film possessing a higher emulsion speed than the Ansco Gun Film while retaining the present grain and resolution. We are now planning an investigation of film plus developer combinations that may enable us to secure better definition with a reasonable film speed.

As experience was gained in predicting the area which could be expected to move following the detonation of the charge, it became possible to establish a field of view which included only that portion of the ground about the charge that would be essential to the analysis. This procedure had the obvious advantage of giving one the maximum amount of information that could be obtained from a given picture, but since no extraneous elements were permitted to appear, the resulting pictures are not particularly interesting to one who is not endeavoring to make an analysis (see Fig. 3).

For the purpose of making pictures that would provide an interesting display, it would be better to have the cameras set to include the entire explosion in the field of view. Although our major interest lay in the investigation of details of the movement of the ground around the charge immediately following the detonation, some incidental pictures

were taken to record the motion of structures near the charge. The thought here was that, while the permanent displacement of the ground beyond the edge of the crater could be determined by other means, the actual motion of the structure just following the detonation might be much more complicated than static measurements could reveal. In a similar manner the permanent displacement of the ground beyond the edge of the crater could be determined by measuring the displacement of stakes driven into it. Such stakes were successfully photographed with the result that unsuspected details of the motion of the ground were revealed. In a few cases we also obtained 16mm Kodachrome pictures of the entire phenomena, using the 70-S Bell & Howell cameras which were set up at a considerable distance from the charge. While from the analyst's standpoint these pictures provide information only about the growth and spread of the dust cloud originating from the explosion, they are of considerable value in that they give an overall picture useful in orienting the observer before looking at the high-speed motion pictures made with the Fastax camera.

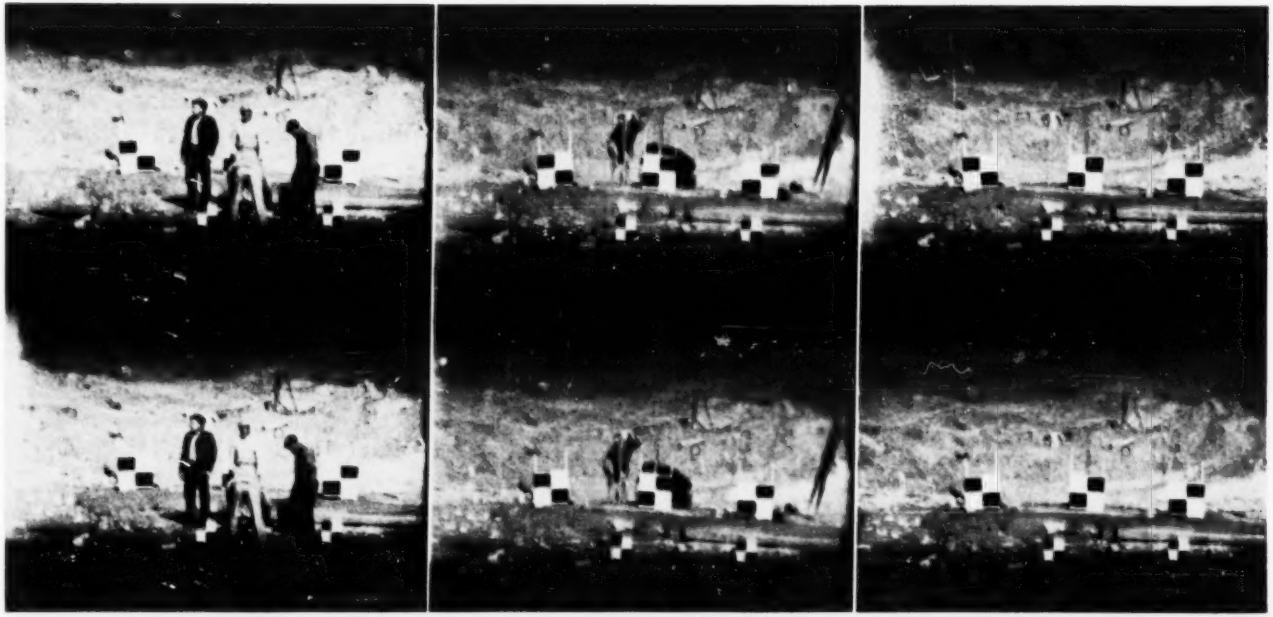
The problem we faced in taking high-speed pictures in the interior of the structures was that of supplying sufficient illumination. Suggestions were made that 60-in. searchlights, or flares of the type employed by the Air Force, could be used. The searchlights, however, require a larger power source than could be moved over the rough terrain, which made them impractical in a field operation of this type. On the other hand, flares are difficult to control, dangerous to handle, and produce large quantities of smoke. We constructed an apparatus consisting of a power supply and a motor-driven commutator connected to set off 40 groups of Sylvania 2A flashbulbs in sequence (see Fig. 5). These bulbs were mounted in reflectors constructed of sheet aluminum along the general lines of an overgrown bread tin standing approximately 36 in. high by 12 in. wide. Each reflector contained two rows of twenty sockets, a pair of reflectors providing a total of 40 pairs of bulbs. The connections to the commutator were such that from 1 to 8 bulbs could be connected in parallel and flashed simultaneously, and the speed of the commutator was set so that 40 sets of bulbs were fired in sequence at such a rate that the maximum-intensity portion of the curves overlapped to provide essentially continuous illumination. This arrangement operated satisfactorily, although field experience made it apparent that improved operation would result from moisture-proofing the electrical equipment and the use of a power source capable of supplying more instantaneous current than the $22\frac{1}{2}$-v radio batteries. For field use this unit had the prime advantage that the energy that supplied the illumination was stored chemically in the flashbulbs and required only triggering energy from a battery, while the motor driving the commutator could be supplied from the same generator that operated the high-speed cameras. With this equipment, it was possible to secure satisfactory pictures when the camera was operated at speeds of approximately 1000 frames/sec and the area to be photographed consisted of 400 sq ft or so. This area was lighted from a distance of approximately 120 ft using 8 flashbulbs to the group; i.e., 320 flashbulbs were used to provide illumination for the two seconds needed to photograph the event. Two cameras were used to photograph the interior of these structures: the Bell & Howell 70-S running at 128 frames/sec and the Fastax set at varying speeds between 132 frames/sec and about 1200 frames/sec. An observation of incidental interest is that the frame rate on the Bell & Howell camera was apparently sufficiently low for the negative to show no flicker in the light source, while the



A. Linagraph Panchromatic.

B. Super XX (not reversal).

C. Linagraph Ortho.



D. Linagraph Shell Burst. E. Eastman Background X. F. Ansco Gun Film.

Fig. 4. A series of prints made from sections of the test negatives taken to determine the film best suited to this program.

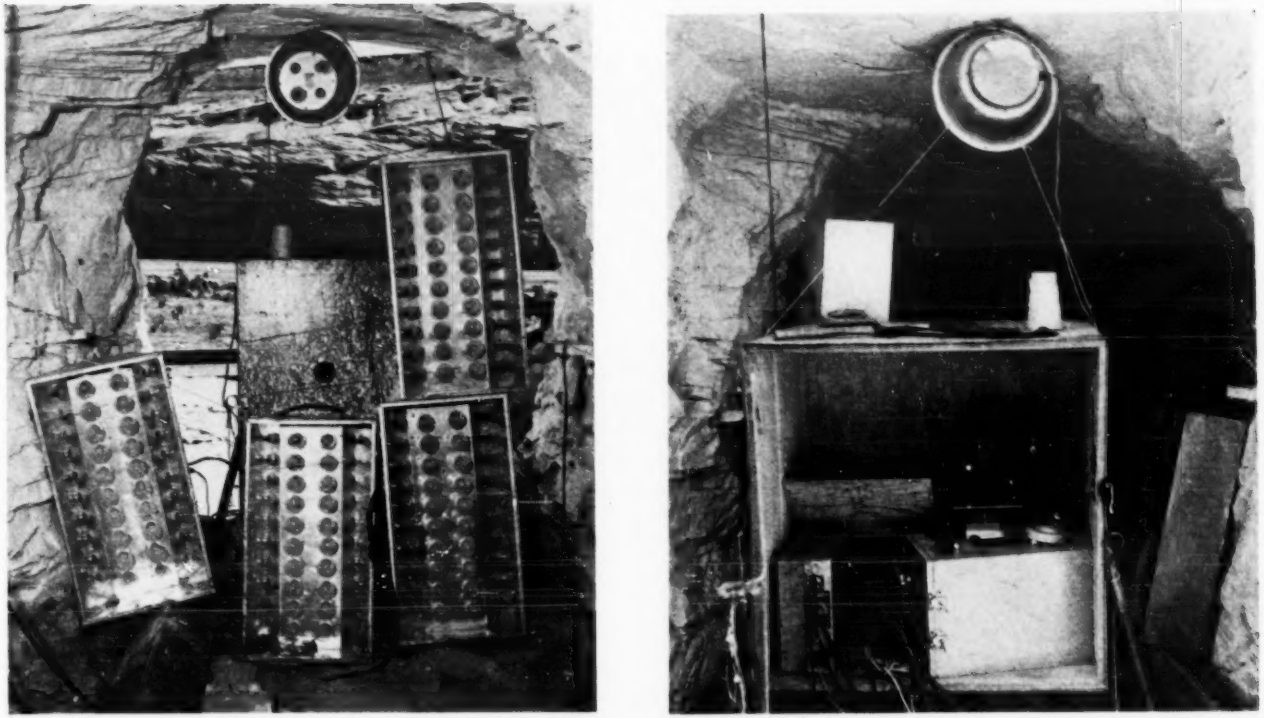


Fig. 5. Camera and lights set up to photograph the interior of a small structure. The camera control equipment is contained in the metal box at the left, the lamp controls are in the wooden box at the right in the rear view of the camera shelter. The camera shelter is built of $\frac{3}{4}$-in. plywood faced with $\frac{1}{4}$-in. steel plate.

Fig. 6. An illustration of the need for camera shelters. The equipment was not seriously damaged.

pictures taken on the Fastax camera at the higher frame rate showed a definite pulsation in the intensity of the illumination. If it were a matter of any importance this could perhaps be overcome by operating the commutator at a different speed, to change the overlap on the peaks of the light output curves from the flashbulbs. The only serious damage sustained by the equipment used inside the structures is shown in Fig. 6.

It is pleasant to be able to say that the Fastax cameras gave trouble-free operation in spite of rough handling and frequent exposure to adverse conditions of excessive dust and moisture. Toward the end of the program, automatic cutoff switches were installed which at first functioned beautifully, but after six weeks one of them stuck shut. Since the camera was timed to catch the event on the last 25 ft of the 100-ft roll, most of the film on which the event was recorded was beaten to confetti during the lengthy over-run.

Therefore we returned to the use of a special control unit built specifically for this operation. These units contained heavy-duty relays designed to control much higher currents than the camera would draw, and pneumatically controlled time-delay relays that were set to provide about 10% more than the calculated running time before shutting off the camera. No failures were experienced with this equipment.

It is our belief that the longer focal length lenses provided for the Fastax camera should be examined for excessive change in focal point when subjected to a temperature change of, say, 30 F. The pictures taken with the 10-in. lens were out of focus, and this may have been caused by the temperature rise that occurred between the setting up of the camera and its operation. Should an examination prove the lens to be temperature sensitive, precautions could be taken to minimize the effect through a redesign of the lens or, if this is not possible, to protect it from changes in temperature.

In a test operation of this magnitude that involves a coordination of the high-speed cameras with a considerable variety of other instrumentation, we suggest that all circuits to the camera be centralized in a special control panel on which signal lamps would be arranged to indicate at all times the condition of each circuit. In addition, apparatus for recording the instant of arrival of the trigger signal at the panel and the subsequent behavior of the circuits should be provided. Although one may be accused of gilding the lily, a means of remotely controlling the Fastax speed and iris settings would have made it possible to secure better pictures in a number of instances.

To the best of our knowledge, no really good equipment is available for reading the films from the high-speed cameras. We have used the Bell & Howell 16mm time-and-motion study projector for some years, but it is not well suited to our needs. The apparatus we would like to have would possess the following features:

1. Ability to rotate the image 15° about the optical axis.

2. Ability to vary the magnification of the image continuously from 15 to 30 times.

3. Better framing, so that a minimum of adjustment is required to cause succeeding frames to coincide exactly on the screen, regardless of the direction in which the film has been moving.

4. Forward and reverse viewing down to 4 frames/sec in addition to single-frame projection.

5. The image should appear on a screen set into a horizontal working surface. The screen might well be set at a small angle, say 20°, to facilitate viewing from a seated position. The screen should be replaceable with a piece of clear glass to permit projecting the image directly on graph paper so that one can obtain a direct tracing of the image.

6. The illumination of the image should be high enough to permit tracing but adjustable by means of a diaphragm to a level comfortable for direct viewing on the ground glass.

7. The entire apparatus should not cost over $1500.

In order to provide the facilities required to process the films obtained on this program, a darkroom was set up in an 8 × 8 × 24 ft trailer. Cabinets and counters of the type employed in modern kitchens were installed and a large sink was provided. In addition to these fundamental items, a small refrigerator for the purpose of storing film, a 35mm contact printer, and a Houston machine were installed in the other end of the trailer. This amount of equipment did not leave a great deal of space for the personnel, and it is our feeling that a somewhat larger trailer would have permitted a more efficient installation, although this arrangement was satisfactory. In connection with

processing in the field, one of the most serious problems is likely to be that of securing a satisfactory supply of water. It was our observation that the greatest difficulty, at least in processing black-and-white film, was likely to be the removal of suspended material. The hardness of the water did not appear to affect the processing. In future operations, we will consider it most important to provide means to remove suspended material and a source of pure water to make up the developing solution. In this respect, water found in the Castledale, Utah, area gave us the greatest amount of trouble, since the material found in it was so finely divided that it passed through even a porous metallic type of filter and deposited a sludge on the photographic material that had to be wiped away. If the emulsion was permitted to dry, the material suspended in the water which had been deposited upon the surface of the film became almost a part of the emulsion and was impossible to remove.

In the desert country in which we were operating, the installation of an effective air-conditioner in the trainer was most essential. The air-conditioning unit broke down for a few days and during this time it was not unusual to have the temperature in the trailer rise to 130 to 140 F. It is, of course, almost impossible to work under these conditions.

In conclusion, I would like to point out that this program was carried on by several organizations besides the Institute of Industrial Research of the University of Denver. The Sacramento District, Corps of Engineers, had established the prime contract with Engineering Research Associates who in turn had subcontracted portions of the work to the Armour Research Foundation, Rensselaer Polytechnic Institute, and the Institute of Industrial Research. Other phases of the program were studied by Stanford Research Institute, Colorado School of Mines, and the U.S. Bureau of Mines. It is a pleasure for me to record here my indebtedness to Dr. W. Ray Jewell, of the University of Denver, for his assistance in solving many of the problems that arose in connection with this program.

Slides and Opaques for Television Film Chains, PH22.94

A PROPOSED STANDARD on slides and opaques for television use is published on the following pages for three months of trial and criticism. All comments should be sent to Henry Kogel, SMPTE Staff Engineer, prior to July 1, 1953. If no adverse comments are received, the proposal will then be submitted to ASA Sectional Committee PH22 for further processing as an American Standard. The proposal was prepared by the Joint RTMA/SMPTE Television Film Equipment Committee.

Work on the proposal was started in 1950. At that time there existed an American Standard on Lantern Slides (Z38.7.149-1950) but it was concerned only with slides intended for direct viewing on a projection screen. The inflexible demand of the television system for a 3 by 4 aspect ratio forced all users to depart from some of the provisions of Z38.7.149. As a result, numerous local standards came into use but there was little agreement among the standards of different organizations or different areas.

When the Committee first explored this subject, it was realized that a major service could be performed simply by securing widespread agreement on the exact dimensions of each of the slide sizes in common use. It also seemed that an additional service might be rendered if agreement could be secured on the use of fewer sizes.

In an initial burst of optimism, the Committee prepared a proposal based on the use of just two sizes. This proposal was widely circulated in 1951 among the membership of the SMPTE, the RTMA, and the National Association of Radio and Television Broadcasters. Responses to this first effort indicated that everyone felt it advisable to accept as standard no more than two sizes. However, there was little or no agreement on the two sizes that should be selected for standardization. Altogether nine sizes were suggested for standardization. The Committee was able to cut this number back to four by insisting that widespread usage *at this time* was a necessary condition for adoption of any size.

At no time has there been any serious objection to the exact dimensions included in the Proposed Standard. Users seem to be content with any number so long as everyone accepts it.—*F. N. Gillette.*

Proposed American Standard

Slides and Opaques for Television Film Chains

(Second Draft)

PH22.94

1. Scope

1.1 This proposal is intended to supplement American Standard Z38.7.19–1950, not replace it. The television system imposes special requirements that did not enter into the preparation of Z38.7.19–1950.

1.2 The proposal applies only to slides and opaques intended for transmission in the standard fashion via a film chain. For other applications, such as background projection, the usual television requirements may not apply.

2. Standard

2.1 Nominal Size. Only the four nominal sizes listed in column 1 of the table shall be considered standard for use in television film chains.

2.2 Overall Dimensions. The overall dimensions for any nominal size shall comply with the dimensions tabulated in column 2. (See Note 1.)

2.3 Dimensions of Transmitted Picture. The portion of the slide or opaque intended for transmission shall lie within a centrally located rectangle having the dimensions shown in column 3. (See Note 2.)

2.4 Dimensions of Picture Background. The background of the slide or opaque shall extend without interruption over a centrally located rectangle having the dimensions shown in column 4. (See Note 2.)

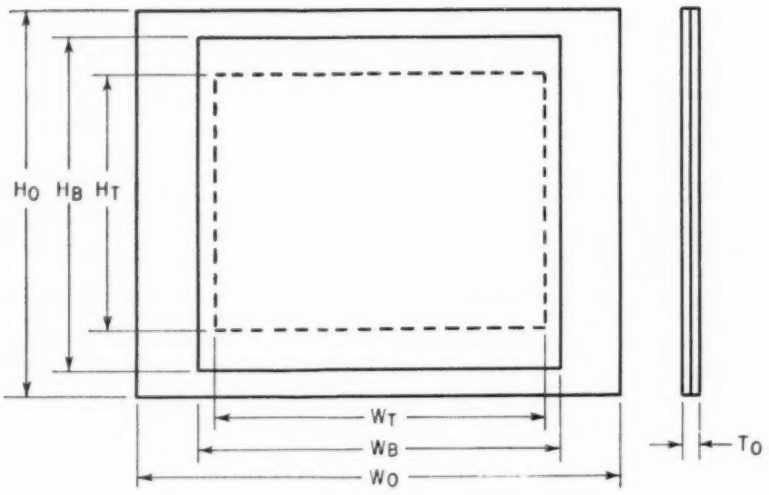
2.5 Centering Tolerance. The center of the transmitted picture rectangle and the center of the background rectangle shall both lie within a circle having as its center the center of the slide and as its radius the dimension tabulated in column 5.

Note 1. The overall dimensions are in accord with American Standard Z38.7.19–1950 insofar as it is relevant. The thickness of opaques is not covered by Z38.7.19–1950. This quantity is here specified as 1/32 inch on the assumption that opaques will consist of double-weight photographic paper without additional support or backing.

Note 2. The dimensions shown for the transmitted picture are those which will be scanned by a perfectly adjusted film chain. To allow for some misadjustment of the film chain and an additional misadjustment in the home receiver, it is recommended that all essential information be contained in a centrally located area appreciably smaller than that specified in column 3.

Note 3. In the case of slides, the background rectangle should be defined by an opaque mask to limit the stray light entering the film chain. The dimensions specified in column 4 permit the use of masks which comply with Z38.7.19–1950. For opaques, masking is generally provided by the projection equipment.

NOT APPROVED



(1) Nominal	(2) Overall			(3) Transmitted Picture		(4) Picture Background		(5) Centering Tolerance
	H_O	W_O	T_O max.	H_T max.	W_T max.	H_B min.	W_B min.	
2 × 2 slide (double 35)	$2\ ^{+0}_{-1/32}$	$2\ ^{+0}_{-1/32}$	1/8	27/32	1 1/8	29/32	1 11/32	1/64
3¼ × 4 slide	$3\frac{1}{4}\ ^{+1/64}_{-1/32}$	$4\ ^{+1/64}_{-1/32}$	5/32	2 1/16	2¾	2¾	3	3/64
3¼ × 4 opaque	$3\frac{1}{4}\ ^{+1/64}_{-1/32}$	$4\ ^{+1/64}_{-1/32}$	1/32	2 1/16	2¾	2¾	3	3/64
4 × 5 opaque	$4 \pm 1/32$	$5 \pm 1/32$	1/32	3	4	3 3/16	4¼	1/16

All dimensions are in inches

NOT APPROVED PH22.94

Constitution of the Society of Motion Picture and Television Engineers

ARTICLE I

Name

The name of this association shall be SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS.

ARTICLE II

Objects

Its objects shall be: Advancement in the theory and practice of engineering in motion pictures, television, and the allied arts and sciences; the standardization of equipment and practices employed therein; the maintenance of a high professional standing among its members; and the dissemination of scientific knowledge by publication.

ARTICLE III

Meetings

There shall be an annual meeting and such other regular and special meetings as provided in the Bylaws.

ARTICLE IV

Eligibility for Membership

Any person of good character is eligible to become a member in any grade for which he is qualified in accordance with the Bylaws.

ARTICLE V

Officers

The officers of the Society shall be a President, an Executive Vice-President, a Past-President, an Engineering Vice-President, an Editorial Vice-President, a Financial Vice-President, a Convention Vice-President, a Secretary, and a Treasurer.

The term of office of all elected officers shall be for a period of two years.

The President shall not be eligible to succeed himself in office.

At the conclusion of his term of office the President automatically becomes Past-President.

Under conditions as set forth in the Bylaws, the office of Executive Vice-President may be vacated before the expiration of his term.

A vacancy in any office shall be filled for the unexpired portion of the term in accordance with the Bylaws.

ARTICLE VI

Sections

Sections may be established in accordance with the Bylaws.

ARTICLE VII

Board of Governors

The Board of Governors shall consist of the President, the Past-President, the five Vice-Presidents, the Secretary, the Treasurer, the Section Chairmen, and twelve elected Governors. An equal number of these elected Governors shall reside within the areas included in the Eastern time zone; the Central time zone; and the Pacific and Mountain time zones. The term of office of all elected Governors shall be for a period of two years.

ARTICLE VIII

Amendments

This Constitution may be amended as follows: Amendments may originate as recommendations within the Board of Governors, or as a proposal to the Board of Governors, by any ten members of voting grade; when approved by the Board of Governors as set forth in the Bylaws, the proposed amendment shall then be submitted for discussion at the annual meeting or at a regular or special meeting called as provided in the Bylaws. The proposed amendment, together with the discussion thereon, shall then be promptly submitted by mail to all members qualified to vote, as set forth in the Bylaws. Voting shall be by letter ballot mailed with the proposed amendment and discussion to the voting membership. In order to be counted, returned ballots must be received within sixty (60) days of the mailing-out date. An affirmative vote of two thirds of the valid ballots returned, subject to the above time limitations, shall be required to carry the amendment, provided one fifteenth of the duly qualified members shall have voted within the time limit specified herein.

BYLAWS OF THE SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

BYLAW I

Membership

Sec. 1. Membership of the Society shall consist of the following grades: Honorary members, Sustaining members, Fellows, Active members, Associate members and Student members.

An *Honorary member* is one who has performed eminent service in the advancement of engineering in motion pictures, television, or allied arts. An Honorary member shall be entitled to vote and to hold any office in the Society.

A *Sustaining member* is an individual, company, or corporation subscribing substantially to the financial support of the Society.

A *Fellow* is one who shall be not less than thirty years of age and who shall by his proficiency and contributions have attained to an outstanding rank among engineers or executives of the motion picture or television industries. A Fellow shall be entitled to vote and to hold any office in the Society.

An *Active member* is one who shall be not less than twenty-five years of age and shall be or shall have been either one or an equivalent combination of the following:

(a) An engineer or scientist in motion picture, television or allied arts. As such he shall have performed and taken responsibility for important engineering or scientific work in these arts and shall have been in the active practice of his profession for at least three years, or

(b) A teacher of motion picture, television or allied subjects for at least six years in a school of recognized standing in which he shall have been conducting a major course in at least one of such fields, or

(c) A person who by invention or by contribution to the advancement of engineering or science in motion picture, television or allied arts, or to the technical literature thereof, has attained a standing equivalent to that required for Active membership in (a), or

(d) An executive who for at least three years has had under his direction important engineering or responsible work in the motion picture, television or allied industries and who is qualified for direct supervision of the technical or scientific features of such activities. An Active member shall be entitled to vote and to hold any office in the Society.

An *Associate member* is one who shall be not less than eighteen years of age, and shall be a person who is interested in the study of motion picture or television technical problems or connected with the application of them. An Associate member is not privileged to vote, to hold office or to act as chairman of any committee, although he may serve upon any committee to which he may be appointed; and, when so appointed, shall be entitled to the full voting privileges on action taken by the committee.

A *Student member* is any person registered as a student, graduate or undergraduate, in a college, university, or other educational institution of like scholastic standing, who evidences interest in motion picture or television technology. Membership in this grade shall not extend more than one year beyond the termination of the student status described above. A student member shall have the same privileges as an Associate member of the Society.

Sec. 2. All applications for membership or transfer should be made on blank forms provided for the purpose, and shall give a complete record of the applicant's education and experience. Honorary and Fellow grades may not be applied for.

Sec. 3. (a) Honorary membership may be granted upon recommendation of the Honorary Membership Committee when confirmed first by a three-fourths majority vote of those present at a meeting of the Board of Governors, and then by a four-fifths majority vote of all voting members present at any regular meeting or at a special meeting called as stated in the bylaws. An Honorary member shall be exempt from the payment of all dues.

(b) Upon recommendation of the Fellow Award Committee, when confirmed by a three-fourths majority vote by those present at a meeting of the Board of Governors, an Active member may be made a Fellow.

(c) An Applicant for Active membership shall give as references at least two members of the grade applied for or of a higher grade. Applicants shall be elected to membership by a three-fourths majority vote of the entire membership of the appropriate Admissions Committee. An applicant may appeal to the Board of Governors if not satisfied with the action of the Admissions Committee, in which case approval of at least three-fourths of those present at a meeting of the Board of Governors shall be required for election to membership or to change the action taken by the Admissions Committee.

(d) An applicant for Associate membership shall give as reference one member of the Society, or two persons not members of the Society who are associated with the motion picture, television, or allied industry. Applicants shall be elected to membership by approval of the Chairman of the appropriate Admissions Committee.

(e) An applicant for Student membership shall be sponsored by a member of the Society, or by a member of the staff of the department of the institution he is attending, this faculty member not necessarily being a member of the Society. Applicants shall be elected to membership by approval of the Chairman of the appropriate Admissions Committee.

Sec. 4. Any member may be suspended or expelled for cause by a majority vote of the entire Board of Governors, provided he shall be given notice and a copy in writing of the charges preferred against him, and shall be afforded opportunity to be heard ten days prior to such action.

BYLAW II

Officers

Sec. 1. An officer or governor shall be an Honorary member, Fellow, or an Active member.

BYLAW III

Board of Governors

Sec. 1. The Board of Governors shall transact the business of the Society in accordance with the Constitution and Bylaws.

Sec. 2. The Board of Governors may act on special resolutions between meetings, by letter ballot authorized by the President. An affirmative vote from a majority of the total membership of the Board of Governors shall be required for approval of such resolutions.

Sec. 3. A quorum of ten members of the Board of Governors shall be present to vote on resolutions presented at any meeting. Unless otherwise specified, a majority vote of the Governors present shall constitute approval of a resolution.

Sec. 4. A member of the Board of Governors may not authorize an alternate to act or vote in his stead.

Sec. 5. Vacancies in the offices or on the Board of Governors shall be filled by the Board of Governors until the annual elections of the Society.

Sec. 6. The Board of Governors, when filling vacancies in the offices or on the Board of Governors, shall endeavor to appoint persons who in the aggregate are representative of the various branches or organizations of the industries interested in the activities of the Society to the end that there shall be no substantial predominance upon the Board, as the result of its own action, of representatives of any one or more branches or organizations of such industries.

Sec. 7. The time and place of all except special meetings of the Board of Governors shall be determined by the Board of Governors.

Sec. 8. Special Meetings of the Board of Governors shall be called by the President with the proviso that no meeting shall be called without at least seven days prior notice to all members of the Board by letter or telegram. Such a notice shall state the purpose of the meeting.

BYLAW IV

Administrative Practices

Sec. 1. Special rules relating to the administration of the Society and known as Administrative Practices shall be established by the Board of Governors and shall be added to or revised as necessary to the efficient pursuit of the Society's objectives.

BYLAW V

Committees

Sec. 1. All committees, except as otherwise specified, shall be formed and appointed in accordance with the Administrative Practices as determined by the Board of Governors.

Sec. 2. All committees, except as otherwise specified, shall be appointed to act for the term served by the officer charged with appointing the committees or until he terminates the appointment.

Sec. 3. Chairmen of the committees shall not be eligible to serve in such capacity for more than two consecutive terms.

Sec. 4. Standing Committees of the Society to be appointed by the President and confirmed by the Board of Governors are as follows:

Honorary Membership Committee
Journal Award Committee
Nominating Committee
Progress Medal Award Committee
Public Relations Committee
Samuel L. Warner Memorial Award Committee

Sec. 5. There shall be an Admissions Committee for each Section of the Society composed of a chairman and three members of which at least two shall be members of the Board of Governors.

Sec. 6. There shall be a Fellow Award Committee composed of all the officers and section chairmen of the Society under the chairmanship of the Past-President. In case the chairmanship is vacated it shall be temporarily filled by appointment by the President.

BYLAW VI

Meetings of the Society

Sec. 1. The location and time of each meeting or convention of the Society shall be determined by the Board of Governors.

Sec. 2. The grades of membership entitled to vote are defined in Bylaw I.

Sec. 3. A quorum of the Society shall consist in number of $\frac{1}{15}$ of the total of those qualified to vote as listed in the Society's records at the close of the last fiscal year before the meeting.

Sec. 4. The annual meeting shall be held during the fall convention.

Sec. 5. Special meetings may be called by the President and upon the request of any three members of the Board of Governors not including the President.

Sec. 6. All members of the Society in any grade shall have the privilege of discussing technical material presented before the Society or its Sections.

BYLAW VII

Duties of Officers

Sec. 1. The President shall preside at all business meetings of the Society and shall perform the duties pertaining to that office. As such he shall be the chief executive of the Society, to whom all other officers shall report.

Sec. 2. In the absence of the President, the officer next in order as listed in Article V of the Constitution shall preside at meetings and perform the duties of the President.

Sec. 3. The seven officers shall perform the duties separately enumerated below and those defined by the President:

(a) The Executive Vice-President shall represent the President, and shall be responsible for the supervision of the general affairs of the Society as directed by the President.

The President and the Executive Vice-President shall not both reside in the geographical area of the same Society Section, but one of these officers shall reside in the vicinity of the executive offices. Should the President or Executive Vice-President remove his residence to the same geographical area of the United States as the other, the office of Executive Vice-President shall immediately become vacant and a new Executive Vice-President shall be elected by the Board of Governors for the unexpired portion of the term.

(b) The Engineering Vice-President shall appoint all technical committees. He shall be responsible for the general initiation, supervision, and co-ordination of the work of these committees.

(c) The Editorial Vice-President shall be responsible for the publication of the Society's *Journal* and all other Society publications.

(d) The Financial Vice-President shall be responsible for the financial operations of the Society, and shall conduct them in accordance with budgets prepared by him and approved by the Board of Governors.

(e) The Convention Vice-President shall be responsible for the national conventions of the Society. He shall arrange for at least one annual convention to be held in the fall of the year.

Sec. 4. The Secretary shall keep a record of all meetings; and shall have the re-

sponsibility for the care and custody of records, and the seal of the Society.

Sec. 5. The Treasurer shall have charge of the funds of the Society and disburse them as and when authorized by the Financial Vice-President. He shall be bonded in an amount to be determined by the Board of Governors, and his bond shall be filed with the Secretary.

Sec. 6. Each officer of the Society, upon the expiration of his term of office, shall transmit to his successor a memorandum outlining the duties and policies of his office.

BYLAW VIII

Society Elections

Sec. 1. All officers and governors shall be elected to their respective offices by a majority of ballots cast by voting members in the following manner:

Nominations shall first be presented by a Nominating Committee appointed by the President, consisting of nine members, including a Chairman. The committee shall be made up of two Past-Presidents, three members of the Board of Governors not up for election, and four other voting members, not currently officers or governors of the Society. Nominations shall be made by three-quarters affirmative vote of the total Nominating Committee.

Not less than three months prior to the Annual Fall Meeting, the Board of Governors shall review the recommendations of the Nominating Committee, which shall have nominated suitable candidates for each vacancy.

Such nominations shall be final unless any nominee is rejected by a three-quarters vote of the Board of Governors present and voting. The Secretary shall then notify these candidates of their nomination. From the list of acceptances, not more than three names for each vacancy shall be selected by the Board of Governors and placed on a letter ballot. A blank space shall be provided on this letter ballot under each office, in which space the name of any voting member other than those suggested by the Board of Governors may be voted for. The balloting shall then take place. The ballot shall be enclosed with a blank envelope and a business reply envelope bearing the Secretary's address and a space for the member's name and address. One set of these shall be mailed to each voting member of the Society, not less than forty days in advance of the Annual Fall Meeting.

The voter shall then indicate on the ballot one choice for each vacancy, seal the ballot in the blank envelope, place this in the envelope addressed to the Secretary, sign his name and address on the latter, and mail it in accordance with the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes. Voting shall close seven days before the opening session of the annual fall convention.

The sealed envelope shall be delivered by the Secretary to a Committee of Tellers appointed by the President at the annual fall convention. This committee shall then examine the return envelopes, open and count the ballots, and announce the results of the election.

The newly-elected officers and governors of the Society shall take office on January 1, following their election.

BYLAW IX

Dues and Indebtedness

Sec. 1. The annual dues shall be fifteen dollars ($15) for Fellows and Active members, ten dollars ($10) for Associate members, and five dollars ($5) for Student members, payable on or before January 1, of each year. Current or first year's dues for new members in any calendar year shall be at the full annual rate for those notified of election to membership on or before June 30; one half the annual rate for those notified of election to membership in the Society on or after July 1.

Sec. 2. (a) Transfer of membership to a higher grade may be made at any time subject to the requirements for initial membership in the higher grade. If the transfer is made on or before June 30, the annual dues of the higher grade are required. If the transfer is made on or after July 1, and the member's dues for the full year have been paid, one half of the annual dues of the higher grade is payable less one half the annual dues of the lower grade.

(b) No credit shall be given for annual dues in a membership transfer from a higher to a lower grade, and such transfers shall take place on January 1, of each year.

Sec. 3. Annual dues shall be paid in advance.

Sec. 4. Failure to pay dues may be considered just cause for suspension.

BYLAW X

Publications

Sec. 1. The Society shall publish a technical magazine to consist of twelve monthly issues, in two volumes per year. The editorial policy of the *Journal* shall be based upon the provisions of the Constitution and a copy of each issue shall be supplied to each member in good standing mailed to his last address of record. Copies may be made available for sale at a price approved by the Board of Governors.

BYLAW XI

Local Sections

Sec. 1. Sections of the Society may be authorized in any locality where the voting membership exceeds twenty. The geographic boundaries of each Section shall be determined by the Board of Governors. Upon written petition for the authorization of a Section of the Society, signed by twenty or more voting members, the Board of Governors may grant such authorization.

Section Membership

Sec. 2. All members of the Society of Motion Picture and Television Engineers in good standing residing within the geographic boundaries of any local Section shall be considered members of that Section.

Sec. 3. Should the enrolled voting membership of a Section fall below twenty, or should the technical quality of the presented papers fall below an acceptable level, or the average attendance at meetings not warrant the expense of maintaining that Section, the Board of Governors may cancel its authorization.

Section Officers

Sec. 4. The officers of each Section shall be a Chairman and a Secretary-Treasurer. The Section chairmen shall be ex-officio members of the Board of Governors and shall continue in such positions for the duration of their terms as chairmen of the local Sections. Each Section officer shall hold office for one year, or until his successor is chosen.

Section Board of Managers

Sec. 5. The Board of Managers shall consist of the Section Chairman, the Section Past-Chairman, the Section Secretary-Treasurer, and six voting members. Each manager of a Section shall hold office for two years. Vacancies shall be filled by appointment by the Board of Managers until the annual election of the Section.

Section Elections

Sec. 6. The officers and managers of a Section shall be voting members of the Society. All officers and managers shall be elected to their respective offices by a majority of ballots cast by the voting members residing in the geographical area of the Section. Not less than three months prior to the annual fall convention of the Society, nominations shall be presented to the Board of Managers of the Section by a Nominating Committee appointed by the Chairman of the Section, consisting of seven members, including a chairman. The committee shall be composed of the present Chairman, the Past-Chairman, two other members of the Board of Managers not up for election, and three other voting members of the Section not currently officers or managers of the Section. Nominations shall be made by a three-quarters affirmative vote of the total Nominating Committee. Such nominations shall be final, unless any nominee is rejected by a three-quarters vote of the Board of Managers, and in the event of such rejection the Board of Managers will make its own nomination.

The Chairman of the Section shall then notify the candidates of their nomination. From the list of acceptances, not more than three names for each vacancy shall be selected by the Board of Managers and placed on a letter ballot. A blank space shall be provided on this letter ballot under each office, in which space the name of any voting member other than those suggested by the Board of Managers may be voted for. The balloting shall then take place. The ballot shall be enclosed with a blank envelope and a business reply envelope bearing the local Secretary-Treasurer's address and a space for the member's name and address. One of these shall be mailed to each voting member of the Society residing in the geographical

area covered by the Section, not less than forty days in advance of the annual fall convention.

The voter shall then indicate on the ballot one choice for each office, seal the ballot in the blank envelope, place this in the envelope addressed to the Secretary-Treasurer, sign his name and address on the latter, and mail it in accordance with the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes. Voting shall close seven days before the opening session of the annual fall convention. The sealed envelopes shall be delivered by the Secretary-Treasurer to his Board of Managers at a duly called meeting. The Board of Managers shall then examine the returned envelopes, open and count the ballots, and announce the results of the election.

The newly-elected officers and managers shall take office on January 1, following their election.

Section Business

Sec. 7. The business of a Section shall be conducted by the Board of Managers.

Section Expenses

Sec. 8. (a) At the beginning of each fiscal year, the Secretary-Treasurer of each section shall submit to the Board of Governors of the Society a budget of expenses for the year.

(b) The Treasurer of the Society shall deposit with each Section Secretary-Treasurer a sum of money for current expenses, the amount to be fixed by the Board of Governors.

(c) The Secretary-Treasurer of each Section shall send to the Treasurer of the Society, quarterly or on demand, an itemized account of all expenditures incurred during the preceding period.

(d) Expenses other than those enumerated in the budget, as approved by the Board of Governors of the Society, shall not be payable from the general funds of the Society without express permission from the Board of Governors.

(e) The Section Board of Managers shall defray all expenses of the Section not provided for by the Board of Governors, from funds raised locally.

(f) The Secretary of the Society shall, unless otherwise arranged, supply to each Section all stationery and printing necessary for the conduct of its business.

Section Meetings

Sec. 9. The regular meetings of a Section shall be held in such places and at such hours as the Board of Managers may designate. The Secretary-Treasurer of each Section shall forward to the Secretary of the Society, not later than five days after a meeting of a Section, a statement of the attendance and of the business transacted.

Constitution and Bylaws

Sec. 10. Sections shall abide by the Constitution and Bylaws of the Society and conform to the regulations of the Board of Governors. The conduct of Sections shall always be in conformity with the general policy of the Society as fixed by the Board of Governors.

BYLAW XII

Student Chapters

Sec. 1. Student Chapters of the Society may be authorized in any college, university, or technical institute of collegiate standing. Upon written petition for the authorization of a Student Chapter, signed by twelve or more Society members, or applicants for Society membership, and the Faculty Adviser, the Board of Governors may grant such authorization.

Chapter Membership

Sec. 2. All members of the Society in good standing who are attending the designated educational institution shall be eligible for membership in the Student Chapter, and when so enrolled they shall be entitled to all privileges that such Student Chapter may, under the Constitution and Bylaws, provide.

Sec. 3. Should the membership of the Student Chapter fall below ten, or the average attendance of meetings not warrant the expense of maintaining the organization, the Board of Governors may cancel its authorization.

Chapter Officers

Sec. 4. The officers of each Student Chapter shall be a Chairman and a Secretary-Treasurer. Each Chapter officer shall hold office for one year, or until his

successor is chosen. Where possible, officers shall be chosen in May to take office at the beginning of the following school year. The procedure for holding elections shall be prescribed in Administrative Practices.

Faculty Adviser

Sec. 5. A member of the faculty of the same educational institution shall be designated by the Board of Governors as Faculty Adviser. It shall be his duty to advise the officers on the conduct of the Chapter and to approve all reports to the Secretary and the Treasurer of the Society.

Chapter Expenses

Sec. 6. The Treasurer of the Society shall deposit with each Chapter Secretary-Treasurer a sum of money, the amount to be fixed by the Board of Governors. The Secretary-Treasurer of the Chapter shall send to the Treasurer of the Society at the end of each school year or on demand an itemized account of all expenditures incurred.

Chapter Meetings

Sec. 7. The Chapter shall hold at least four meetings per year. The Secretary-Treasurer shall forward to the Secretary of the Society at the end of each school year a report of the meetings for that year, giving the subject, speaker, and approximate attendance for each meeting.

BYLAW XIII

Amendments

Sec. 1. Proposed amendments to these Bylaws may be initiated by the Board of Governors or by a recommendation to the Board of Governors signed by ten voting members. Proposed amendments may be approved at any regular meeting of the Society at which a quorum is present, by the affirmative vote of two-thirds of the members present and eligible to vote thereon. Such proposed amendments shall have been published in the *Journal* of the Society, in the issue next preceding the date of the stated business meeting of the Society at which the amendment or amendments are to be acted upon.

Sec. 2. In the event that no quorum of the voting members is present at the time of the meeting referred to in Sec. 1, the amendment or amendments shall be referred for action to the Board of Governors. The proposed amendment or amendments then become a part of the Bylaws upon receiving the affirmative vote of three-quarters of the entire membership of the Board of Governors.

BYLAW XIV

Standards and Recommendations

Sec. 1. American Standards sponsored by the Society and the Society's Recommendations are proposed and adopted in the public interest and are designed to eliminate misunderstanding between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for its particular need. Existence of such a Standard or Recommendation does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the Standard or Recommendation.

BYLAW XV

Disposition of Assets and Dissolution

Sec. 1. Upon the dissolution of the Society and after payment of all indebtedness of the Society, the funds, investments and other assets of the Society shall be given and transferred to some other nonprofit organization having objects similar to those of the Society. The selection of such other organization shall be made by the Board of Governors either at a regular meeting of said Board of Governors or at a special meeting of said Board called for the purpose of selecting such an organization.

Officers of the Society April 1953

JOHN G. FRAYNE
Executive Vice-President
1953–54

HERBERT BARNETT
President
1953–54

PETER MOLE
Past-President
1953–54

HENRY J. HOOD
Engineering Vice-President
1953–54

NORWOOD L. SIMMONS
Editorial Vice-President
1953–54

FRANK E. CAHILL, JR.
Financial Vice-President
1953–54

JOHN W. SERVIES
Convention Vice-President
1953–54

EDWARD S. SEELEY
Secretary
1953–54

BARTON KREUZER
Treasurer, 1953–54

J. E. AIKEN
Governor, 1952–53

FRED G. ALBIN
Governor, 1952–53

GEORGE W. COLBURN
Governor, 1952–53

ELLIS W. D'ARCY
Governor, 1952–53

JOHN K. HILLIARD
Governor, 1952–53

AXEL G. JENSEN
Governor, 1952–53

FRANK E. CARLSON
Governor, 1953–54

GORDON A. CHAMBERS
Governor, 1953–54

L. M. DEARING
Governor, 1953–54

WM. A. MUELLER
Governor, 1953–54

CHARLES L. TOWNSEND
Governor, 1953–54

MALCOLM G. TOWNSLEY
Governor, 1953–54

C. E. HEPPBERGER
Governor, 1953

WM. H. OFFENHAUSER, JR.
Governor, 1953

VAUGHN C. SHANER
Governor, 1953

OFFICERS AND MANAGERS OF SECTIONS

ATLANTIC COAST: Chairman, Wm. A. Offenhauser, Jr.; *Secretary-Treasurer*, Emerson Yorke; *Managers:* R. C. Holslag, M. H. Searle, R. T. Van Niman, Frank N. Gillette, John G. Stott, Richard Hodgson.

CENTRAL: Chairman, C. E. Heppberger; *Secretary-Treasurer*, J. L. Wassell; *Managers:* R. Paul Ireland, Wm. P. Kusak, John S. Powers, K. M. Mason, W. C. Eddy, I. F. Jacobsen.

PACIFIC COAST: Chairman, Vaughn C. Shaner; *Secretary-Treasurer*, P. C. Caldwell; *Managers:* Ralph E. Lovell, Hollis W. Moyse, Herbert Pangborn, A. C. Blaney, L. G. Dunn, A. M. Gundelfinger.

STUDENT CHAPTER OFFICERS

NEW YORK UNIVERSITY:
Under Re-organization

UNIVERSITY OF SOUTHERN CALIFORNIA: Chairman, K. Kenneth Miura; *Secretary-Treasurer*, Richard Polister.

K. KENNETH MIURA
Chairman, 1953

Treasurer's Report—January 1 — December 31, 1952

CASH			
Cash on Deposit, Regular Account, Chase National Bank, January 1, 1952		$ 2,237	
Net Receipts		11,407	
Cash on Deposit, Regular Account, December 31, 1952			$13,644
Cash on Deposit, Payroll Account, Chase National Bank, January 1, 1952	98		
Deposits	$48,602		
Total		48,700	
Disbursements		48,141	
Cash on Deposit, Payroll Account, December 31, 1952			559
Petty Cash Fund			200
Total Cash on Deposit and on Hand			$14,403
INVESTMENTS			
Savings Accounts, January 1, 1952	27,209		
Less: Accounts Closed	21,612		
Total	5,597		
Add: Interest Credited	198		
Savings Accounts, December 31, 1952		5,795	
U.S. Government Bonds (at cost)		60,000	
Total Investments			65,795
Total Cash and Investments, December 31, 1952			$80,198

Respectfully submitted,
BARTON KREUZER, *Treasurer*

Summary of Financial Condition—Dec. 31, 1952

ASSETS (What Your Society Owns)	
Cash on Hand and in Bank	$ 14,403
Savings Accounts	5,795
U.S. Government Bonds (at cost)	60,000
Accounts Receivable	6,815
Test Film Inventory	47,130
Test Film Equipment (memo value)	1
Office Furniture and Equipment (memo value)	1
Total Assets	$134,145
LIABILITIES (What Your Society Owes)	
Accounts Payable	$ 4,339
Customers' Advance Payments	586
Membership Dues Received in Advance	4,082
Withholding Taxes Payable	1,472
N.Y.C. Sales Tax Payable	10
F.O.A.B. Payable	129
Federal Excise Tax Payable	17
Reserve for Replacement of Test Film Equipment	8,000
Reserve for 1955 Five Year Index	1,000
Total Liabilities	$ 19,635
MEMBERS' EQUITY (What Your Society Is Worth)	114,510
Total Liabilities and Members' Equity	$134,145

Statement of Income and Expenses

January 1 — December 31, 1952

Test Film Operations		
Test Film Sales	$98,193	
Cost of Test Films Sold	61,739	
Net Income From Test Film Operations		$36,454
Membership Operations		
Total Membership Dues Income	$67,798	
Total Cost of Membership Operations	7,494	
Net Income From Membership Operations		60,304
Publications Operations		
Total Income from Publications	$21,149	
Total Cost of Publications Operations	49,320	
Net Loss From Publications Operations		(28,171)
Conventions Operations		
Total Income From Conventions	$11,243	
Total Cost of Conventions Operations	14,290	
Net Loss From Conventions Operations		(3,047)
Other Sales Operations		
Total Other Sales	$ 1,058	
Total Cost of Other Sales Operations	905	
Net Income From Other Sales Operations		153
Other Income		
Interest Earned	$ 1,648	
Miscellaneous Income	97	
Total Other Income		1,745
Total Operating Income		$67,438
Operating Expenses		
Engineering	$12,025	
Nonengineering Committees	398	
Administrative	55,542	
Officers	323	
Sections and Chapters	2,600	
Affiliations	1,385	
Total Operating Expenses		72,273
Net Operating Income		($4,835)
Other Deductions		
Provision for Replacement of Test Film Equipment	$ 8,000	
Provision for 1955 Five-Year Index	500	
Total Other Deductions		8,500
Excess of Expenses Over Income		($13,335)

The foregoing financial statements were prepared from the records of the Society for the year 1952 and reflect the results of operations for that year. The records and financial statements were audited for the year ended December 31, 1952, by Wilbur A. Smith, Certified Public Accountant, New York City, and are in conformity with that audit.

FRANK E. CAHILL, JR., *Financial Vice-President*

Membership Report

For Year Ended December 31, 1952

	Hon.	Fel.	Act.	Assoc.	Stud.	Total Indiv.	Sust.	Total Memb.
Membership, January 1, 1952	3	207	1114	1873	215	3412	76	3488
New Members			193	317	72	582	10	592
Reinstatements			7	15	1	23		23
	3	207	1314	2205	288	4017	86	4103
Resignations		−1	−17	−37	−2	−57	−1	−58
Deceased		−2	−3	−8		−13		−13
Delinquent			−78	−144	−70	−292	−4	−296
	3	204	1216	2016	216	3655	81	3736
Transfers:								
Active to Fellow		15	−15					
Associate to Active			69	−69				
Student to Active			2		−2			
Student to Associate				10	−10			
Active to Associate			−6	6				
Membership, December 31, 1952	3	219	1266	1963	204	3655	81	3736

Nonmember Subscription Report

For Year Ended December 31, 1952

Subscriptions, January 1, 1952	1,028
New Subscriptions and Previous Cutoffs	467
	1,495
Cutoffs and Expirations	277
Subscriptions, December 31, 1952	1,218

Journal on Microfilm

University Microfilms has announced the completion of microfilming the *Journal* for 1952. The year's two volumes, 58 and 59, are packaged as one unit which sells for $3.45. These volumes as well as those for 1950 and 1951 are available to Society members and *Journal* subscribers for those years. The costs are $4.15 for 1950 (vols. 54 and 55) and $4.00 for 1951 (vols. 56 and 57). Address all inquiries to University Microfilms, 313 N. First St., Ann Arbor, Mich.

Awards

In accordance with the provisions of the Administrative Practices of the Society and the regulations for granting the Journal Award, the Progress Medal Award, the Samuel L. Warner Memorial Award and the David Sarnoff Gold Medal Award, a list of names of previous recipients and the reasons for the awards are published annually in the *Journal* as follows:

Journal Award

The Journal Award Committee shall consist of five Fellows or Active members of the Society, appointed by the President and confirmed by the Board of Governors. The Chairman of the Committee shall be designated by the President.

At the fall convention of the Society a Journal Award Certificate shall be presented to the author or to each of the authors of the most outstanding paper originally published in the *Journal* of the Society during the preceding calendar year.

Other papers published in the *Journal* of the Society may be cited for Honorable Mention at the option of the Committee, but in any case should not exceed five in number.

The Journal Award shall be made on the basis of the following qualifications:

(1) The paper must deal with some technical phase of motion picture engineering.

(2) No paper given in connection with the receipt of any other Award of the Society shall be eligible.

(3) In judging of the merits of the paper, three qualities shall be considered, with the weights here indicated: (a) technical merit and importance of material, 45%; (b) originality and breadth of interest, 35%; and (c) excellence of presentation of the material, 20%.

A majority vote of the entire Committee shall be required for the election to the Award. Absent members may vote in writing.

The report of the Committee shall be presented to the Board of Governors at their July meeting for ratification.

These regulations, a list of the names of those who have previously received the Journal Award, the year of each Award, and the titles of the papers shall be published annually in the *Journal* of the Society. In addition, the list of papers selected for Honorable Mention shall be published in the *Journal* of the Society during the year current with the Award.

The recipients are listed below by year, with the date of *Journal* publication given after the title.

1934, P. A. Snell, "An introduction to the experimental study of visual fatigue," May 1933.

1935, L. A. Jones and J. H. Webb, "Reciprocity law failure in photographic exposure," Sept. 1934.

1936, E. W. Kellogg, "A comparison of variable-density and variable-width systems," Sept. 1935.

1937, D. B. Judd, "Color blindness and anomalies of vision," June 1936.

1938, K. S. Gibson, "The analysis and specification of color," Apr. 1937.

1939, H. T. Kalmus, "Technicolor adventures in cinemaland," Dec. 1938.

1940, R. R. McNath, "The surface of the nearest star," Mar. 1939.

1941, J. G. Frayne and Vincent Pagliarulo, "The effects of ultraviolet light on variable-density recording and printing, June 1940.

1942, W. J. Albersheim and Donald MacKenzie, "Analysis of soundfilm drives," July 1941.

1943, R. R. Scoville and W. L. Bell, "Design and use of noise-reduction bias systems," Feb. 1942 (Award made Apr. 1944).

1944, J. I. Crabtree, G. T. Eaton and M. E. Muehler, "Removal of hypo and silver salts from photographic materials as affected by the composition of the processing solutions," July 1943.

1945, C. J. Kunz, H. E. Goldberg and C. E. Ives, "Improvement in illumination efficiency of motion picture printers," May 1944.

1946, R. H. Talbot, "The projection life of film," Aug. 1945.

1947, Albert Rose, "A unified approach to the performance of photographic film, television pickup tubes, and the human eye," Oct. 1946.

1948, J. S. Chandler, D. F. Lyman and L. R. Martin, "Proposals for 16-mm and 8-mm sprocket standards," June 1947.

1949, F. G. Albin, "Sensitometric aspect of television monitor-tube photography," Dec. 1948.

1950, Frederick J. Kolb, Jr., "Air cooling of motion picture film for higher screen illumination," Dec. 1949.

1951, A. B. Jennings, W. A. Stanton and J. P. Weiss, "Synthetic color-forming binders for photographic emulsions," Nov. 1950.

1952, D. L. MacAdam, "Quality of color reproduction," May 1951.

The present Chairman of the Journal Award Committee is Frederick J. Kolb, Jr.

Progress Medal Award

The Progress Medal Award Committee shall consist of five Fellows or Active members of the Society, appointed by the President and confirmed by the Board of Governors. The Chairman of the Committee shall be designated by the President.

The Progress Medal may be awarded each year to an individual in recognition of any invention, research or development which, in the opinion of the Committee, shall have resulted in a significant advance in the development of motion picture technology.

Any member of the Society may recommend persons deemed worthy of the Award. The recommendation in each case shall be in writing and in detail as to the accomplishments which are thought to justify consideration. The recommendation shall be seconded in writing by any two Fellows or Active members of the Society, who shall set forth their knowledge of the accomplishments of the candidate which, in their opinion, justify consideration.

A majority vote of the entire Committee shall be required to constitute an Award of the Progress Medal. Absent members may vote in writing.

The report of the Committee shall be presented to the Board of Governors at their July meeting for ratification.

The recipient of the Progress Medal shall be asked to present a photograph of himself to the Society and, at the discretion of the Committee, may be asked to prepare a paper for publication in the *Journal* of the Society.

These regulations, a list of the names of those who have previously received the Medal, the year of each Award and a statement of the reason for the Award shall be published annually in the *Journal* of the Society.

Awards have been made as follows:

1935, E. C. Wente, for his work in sound recording and reproduction, Dec. 1935.

1936, C. E. K. Mees, for his work in photography, Dec. 1936.

1937, E. W. Kellogg, for his work in sound reproduction, Dec. 1937.

1938, H. T. Kalmus, for his work in developing color motion pictures, Dec. 1938.

1939, L. A. Jones, for his scientific researches in photography, Dec. 1939.

1940, Walt Disney, for his contributions to motion picture photography and sound recording of feature and short cartoon films, Dec. 1940.

1941, G. L. Dimmick, for his development activities in motion picture sound recording, Dec. 1941.

No Awards were made in 1942 and 1943.

1944, J. G. Capstaff, for his research and development of films and apparatus used in amateur cinematography, Jan. 1945.

No Awards were made in 1945 and 1946.

1947, J. G. Frayne, for his technical achievements and the documenting of his work in addition to his contributions to the field of education and his inspiration to his fellow engineers, Jan. 1948.

1948, Peter Mole for his outstanding achievements in motion picture studio

lighting which set a pattern for lighting techniques and equipment for the American motion picture industry, Jan. 1949.

1949, Harvey Fletcher for his outstanding contributions to the art of recording and reproducing of sound for motion pictures, Oct. 1949

1950, V. K. Zworykin, for his outstanding contributions to the development of television, Dec. 1950.

1951, Earl I. Sponable, for outstanding contributions to technical advancement of the motion picture art, particularly with respect to sound on film, color and large-screen television, Dec. 1951.

1952, John I. Crabtree, for his outstanding contribution in the field of photographic chemistry, motion picture processing and processing equipment, Dec. 1952.

The present Chairman of the Progress Medal Award Committee is D. B. Joy.

Samuel L. Warner Memorial Award

Each year the President shall appoint a Samuel L. Warner Memorial Award Committee consisting of a chairman and four members. The chairman and committee members must be Active Members or Fellows of the Society. In considering candidates for the Award, the committee shall give preference to inventions or developments occurring in the last five years. Preference should also be given to the invention or development likely to have the widest and most beneficial effect on the quality of the reproduced sound and picture. A description of the method or apparatus must be available for publication in sufficient detail so that it may be followed by anyone skilled in the art. Since the Award is made to an individual, a development in which a group participates should be considered only if one person has contributed the basic idea and also has contributed substantially to the practical working out of the idea. If, in any year, the committee does not consider any recent development to be more than the logical working out of details along well-known lines, no recommendation for the Award shall be made. The recommendation of the committee shall be presented to the Board of Governors at the July meeting.

The purpose of this Award is to encourage the development of new and improved methods or apparatus designed for sound-on-film motion pictures, including any step in the process.

Any person, whether or not a member of the Society of Motion Picture and Television Engineers, is eligible to receive the Award.

The Award shall consist of a gold medal suitably engraved for each recipient. It shall be presented at the Fall Convention of the Society, together with a bronze replica.

These regulations, a list of those who previously have received the Award, and a statement of the reason for the Award shall be published annually in the *Journal* of the Society. The recipients have been:

1947, J. A. Maurer, for his outstanding contributions to the field of high-quality 16-mm sound recording and reproduction, film processing, development of 16-mm sound test films, and for his inspired leadership in industry standardization (citation published, Jan. 1948).

1948, Nathan Levinson, for his outstanding work in the field of motion picture sound recording, the intercutting of variable-area and variable-density sound tracks, the commercial use of control track for extending volume range, and the use of the first soundproof camera blimps (citation published, Jan. 1949).

1949, R. M. Evans, for his outstanding work in the field of color motion picture films, including research on visual effects in photography and development work on commercial color processes (citation published, Oct. 1949).

1950, Charles R. Fordyce, for his efforts in and achievement of the development of triacetate safety base film (citation published, Dec. 1950).

1951, Earl I. Sponable, for years of research and development in recording of sound on film (citation published Dec. 1951).

1952, Herbert T. Kalmus; for Techni-

color's perfection of the inhibition process for 16mm color prints and for the techniques of making separate sound negatives for mass production by the 35mm32mm method for excellence of 16mm sound (citation published, Dec. 1952).

The present Chairman of the Samuel L. Warner Memorial Award Committee is Wallace V. Wolfe.

David Sarnoff Gold Medal Award

The David Sarnoff Gold Medal Award Committee, appointed by the President, shall consist of five Fellows, Honorary Members or former recipients of some formal Society Award, each of whom shall be qualified to judge the importance or value of current work in some technical phase of the broad field of television engineering, whether in research, development, design, manufacture, operation, or in any similar phase of theater television.

The award shall consist of a gold medal, together with a bronze replica and a citation, stating the recipient's qualifications.

The David Sarnoff Gold Medal may be awarded each year to any qualified individual, whether or not currently a member of this Society, in recognition of recent technical contributions to the art of television, to encourage the development of new techniques, new methods and new equipment which hold promise for the continued improvement of television, preference to be given for work having reached completion within the preceding five years.

Recommendations of the Committee and a report of its deliberations shall be presented to the Board of Governors three months in advance of the time for presentation (at the July meeting of the Board, for presentation at the Fall Convention). Any member of the Society may recommend persons deemed worthy of the Award. The recommendation in each case shall be in writing and in detail as to the accomplishments which are thought to justify consideration.

These regulations, a list of the names of those who have previously received the medal, the year of each Award and a statement of the reason for the Award shall be published annually in the *Journal* of the Society. The first recipient is:

1951, Otto H. Schade, for his outstanding accomplishments in the fields of television and motion picture science and engineering, in outlining the potentialities of television and film systems as to fidelity of photography and reproduction of images (citation published Dec. 1951).

1952, Axel G. Jensen, for his manifold contributions to the promulgating of monochrome and color television engineering standards, and for his work on the improvement of the quality of television pictures obtained from motion picture film (citation published, Dec. 1952).

The present Chairman of the David Sarnoff Gold Medal Award Committee is Loren L. Ryder.

Tests films are solidly noticed in the *Bulletin* of the Audio-Visual Center, Indiana University, Bloomington, Ind., vol. 12, No. 3, Feb. 1953. The first three pages are chiefly devoted to the Society's *16mm Sound Service Test Film*, the values of which have been emphasized for the *Bulletin* by Robert W. Miller of the De Vry Corp. After a thorough description of the sound service film, there is this note: "We hope that information on a visual test film can be presented in this *Bulletin* in the near future. If you have had experience in using one, or can suggest points which need to be discussed, we will appreciate hearing from you."

HONORARY MEMBERS

Lee de Forest
Edward W. Kellogg
A. S. Howell
V. K. Zworykin

The distinction of Honorary Membership in the Society is awarded to living pioneers whose basic contributions when examined through the perspective of time represent a substantial forward step in the recorded history of the arts and sciences with which the Society is most concerned.

SMPTE HONOR ROLL

Louis Aimé Augustin Le Prince
William Friese-Greene
Thomas Alva Edison
George Eastman
Frederic Eugene Ives
Jean Acme Le Roy
C. Francis Jenkins
Eugene Augustin Lauste
William Kennedy Laurie Dickson
Edwin Stanton Porter
Herman A. DeVry
Robert W. Paul
Frank H. Richardson
Leon Gaumont
Theodore W. Case
Edward B. Craft
Samuel L. Warner
Louis Lumiere
Thomas Armat

Elevation to the Honor Roll of the Society is granted to each distinguished pioneer who during his lifetime was awarded Honorary Membership or whose work was recognized subsequently as fully meriting that award.

Engineering Activities

Film Projection Practice Committee

On March 10, 1953, the members of this Committee met to consider several very timely questions that have been raised with respect to special magazines, projection reels and reel spindles required for exhibition of three-dimensional motion pictures.

Their deliberations produced a number of definite recommendations and suggestions that further engineering development work be undertaken promptly by the equipment manufacturers. The Committee's letter of March 18 transmitting this information to the manufacturers said:

In order possibly to help eliminate confusion on magazines and reels for use with 3-D, two-film systems accommodating a program length of 10,000 ft with one intermission, we list below the present thinking of the Film Projection Practice Committee of the SMPTE:

Magazines

A magazine with an inside diameter of 25 in. and minimum depth of 3½ in. is recommended.

Reels and Spindles

A reel with an outside diameter of 24 in. is recommended. Suggestions on other features of this equipment follow:

(a) Several manufacturers indicated that a $\frac{5}{16}$-in. diameter shaft of high-grade steel is adequate with regard to strength. However, to provide a reasonable safety factor where suitable steel cannot be used a ½-in. spindle may be desirable.

(b) It is believed that a $\frac{5}{16}$- or ½-in. bore in the reel is inadequate and that a larger bore is definitely required. The reasons are twofold:

(1) It is extremely difficult to place a loaded 24-in. reel on the feed magazine spindle when sighting through a $\frac{5}{16}$- or ½-in. bore, especially when it is con-

sidered that this spindle is above the line of sight of the average projectionist.

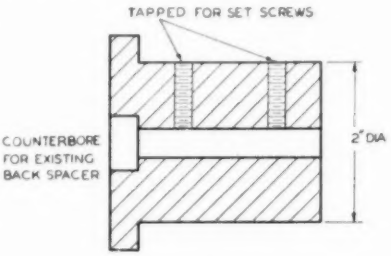
(2) Necessary manufacturing tolerances and subsequent wear between reel bore and spindle shaft cause lateral motion of the reel rim regardless of reel size. However, this deviation from a true running reel increases proportionately as the outside diameter increases. This weave effect is inversely proportional to the size of the spindle shaft and reel bore: the larger the diameter of the shaft and bore, the smaller the weave, assuming, of course, the same play between spindle and reel exists in all cases.

It is believed that a 2-in. diameter reel bore would appreciably aid in overcoming these difficulties.

(c) Transition from $\frac{5}{16}$-in. or $\frac{1}{2}$-in. diameter shaft to the 2-in. diameter bore can be accomplished with an adapter which is secured to the shaft with two Allen head setscrews. This adapter could carry a $\frac{1}{8}$-in. key on its outside diameter for engagement with the keyway in the reel bore and have a suitable internal keyway for engagement with the key in the magazine shaft. Additional details on the adapter are shown in the diagram herewith.

Goal

With these suggested modifications restricted initially to the theater projection booth, it is believed that the equipment conversion will proceed smoothly and with a minimum of obsolescence of existing equipment. It is contemplated that over a period of years and with the development of new equipment the adapter will become an integral part of the spindle. This would provide an additional engineering improvement because the driving torque would then come directly from the larger-diameter member, eliminating the wear resulting from the existing drive.



SECTION THROUGH ADAPTER

Program

The Committee does not wish to offer these proposals as recommendations until samples have been built and tested. Since this is an industry-wide problem, we would appreciate it if your company would provide and run tests on a single unit as described above. If you like, the Committee can submit your test unit to several theater operators for further test and comment. If, in reviewing this with your own engineers, you have any suggestions for improvements, we shall very much appreciate your help, since this, of course, is a problem which is in urgent need of an engineering solution acceptable to the whole industry.—*Henry Kogel*, Staff Engineer.

Errata

Eugene Millet, "Some Geometrical Conditions for Depth Effect in Motion Pictures," *Jour. SMPTE, 59:* 517–523, Dec. 1952.

Page 519, equation (15):

For: $X_v = D'f_pX_v/f_vX_p = 0$
read: $X_v - D'f_pX_v/f_vX_p = 0$

Page 519, equation (20):

For: $\alpha' - ab_v/X_v(X_v - a).$
read: $\alpha' = ab_v/X_v(X_v - a).$

Page 520, column 1, line 20:

For: $E_t' - 1$
read: $E_t' < 1$

Page 520, column 1, lines 29, 30 and 31:

For: Having assumed $E_t' - 1$, we have $D/E_t' - D$ and $E_a/E_a' - 1$ or $E_a' - E_a$.
read: Having assumed $E_t' < 1$, we have $D/E_t' > D$ and $E_a/E_a' < 1$ or $E_a' > E_a$.

Page 521, column 1, equation (21):

For: $\gamma_1 - \gamma_2 - 2b_a(1/D_1 - 1/D_2)$
read: $\gamma_1 - \gamma_2 = 2b_a(1/D_1 - 1/D_2)$

Page 521, column 2, line 4:

For: $D_1 - 1.95$ m
read: $D_1 = 1.95$ m

Page 523, column 1, line 19:

For: $(64/3000)12.5 - 5.3 = 5.57$
read: $(64/3000)12.5 + 5.3 = 5.57$

Central Section Meeting

Meeting on March 19, the Managers authorized an expenditure for imprinted envelopes which should establish control over mailings and prevent a reoccurrence of the mix-up which kept perhaps as much as half the membership from receiving their notices for this meeting. George Negus reported on a Chicago Technical Council Meeting of Program Chairmen. It was agreed that an article describing the functions of the Central Section would be prepared for publication in the local Sci-En-Tech.

In line with our plans to bring more basic papers to the members, our May 21st meeting will be at the Western Society of Engineers and will run from midafternoon until approximately 10:30. We plan to invite manufacturers to exhibit magnetic striping products and equipment in the small auditorium. In the large auditorium two papers are scheduled between 4:00 and 5:30 P.M. These will cover application of magnetic recording. There will be a six-to-eight dinner break and individual conferences may be held with manufacturers' representatives.

Starting at 8:00 P.M. Dr. W. W. Wetzel, of Minnesota Mining and Manufacturing Co., will keynote the session with a paper entitled "Basic Theory of Magnetic Recording." Following Dr. Wetzel, a general panel discussion on the entire field of magnetic recording will begin. Paul Ireland is cooperating with George Negus on this ambitious meeting. This is the first specific example of our stated program for the Managers to carry extra duties.

The Managers' March 19 meeting adjourned at 6:00 P.M. and the general meeting was convened at 8:00 P.M. The program was:

"Combat Photography," Norman Hatch, former Marine Corps Cinematographer presented the film *Battle of Tarawa* which was made during the invasion. His discussion covered the reasons behind the picture, the experiences of the photographer during the shooting and the technical problems of combat photography.

"Stereo Today," Robert L. McIntyre, photographic consultant and columnist, a discussion of principles and applications of stereo.

A demonstration of stereo projection with color slides, by Earl Krause, Vice-Chairman of the Stereo Division of PSA.

"Light Polarization as It Applies to Stereo Projection," by Robert Hall.

Approximately 90 people attended, which was excellent considering that not many had received notification because of the partial failure in mailing.—*James L. Wassell*, Secretary-Treasurer, Central Section, 247 E. Ontario St., Chicago 11, Ill.

Book Review

Auditoriums

No. 2 in a series, Planning Schools for Use of Audio-Visual Materials. Published (1953) by the Department of Audio-Visual Instruction, National Education Association, 1201 16th St., N.W., Washington 6, D.C. 36 pp. 13 illus. Paper bound. 6 × 9 in. Price $1.00 (discounts for quantities).

Auditoriums is another result of a conference on audio-visual instruction which was reported by D. F. Lyman in the *Journal*, pp. 445–449, May 1952. Society members will be interested inasmuch as the booklet offers "basic performance standards for adequate utilization of motion pictures, slides, filmstrips, radio, television, recordings, opaque materials, and display and exhibit materials for groups larger than the single class unit."

Seating arrangements are suggested, and guidance is given for planning of an "activity area" of at least 15 to 20 ft between the stage and the front row of seats, furnished with a portable projection screen, microphone, electrical outlets, folding chairs, etc. Problems of acoustics are emphasized, and guidance from a qualified consultant is strongly urged. The use of splayed walls and of windowless walls are two modern trends in school auditoriums that are favored in dealing with acoustics problems.

A few pointers on wiring emphasize that it is cheaper to provide at the time of construction more outlets than are thought necessary than to add a few later. A check list is provided.

Methods of darkening auditoriums for motion picture projection, the desirable light level in the darkened hall, and screen surround are outlined under "Light Control," and under "Speakers" it is suggested that a sound-system specialist, not the "local radio-man," be consulted on selection and installation.

The selection and placement of projection screens are covered and available types described. Projection niches for small auditoriums and booths for large ones are specified. The final section outlines who should select equipment and how it should be chosen, with a list of some specific points to consider. An appendix lists 54 manufacturers of pertinent equipment.

This well-done booklet, like its predecessor, is chiefly a public-relations product. It should be useful to the specialists to put in the hands of the layman in order to win support for new proposals. The designer or engineer who is concentrating on his job may find himself grateful to this educationists' group for verbalizing his ideas in terms understandable to the man who will pay the bill.—*V.A.*

New Audio Periodical

The Audio Engineering Society has established a quarterly *Journal* under the editorship of Lewis S. Goodfriend. The first issue has been announced to contain the 30 papers presented last October at the Fourth Annual Convention of the Society. The *Journal* is conceived as a medium for review and original research articles on broadcast audio systems, the recording and reproduction of sound (musical and otherwise), and certain other topics of particular interest to the professional audio engineer. Book reviews and other items of current interest will be published. Subscriptions may be entered by nonmembers at $8.00 per year, by addressing the *Journal* of the Audio Engineering Society, P.O. Box 12, Old Chelsea Station, New York 11, N.Y. AES members will receive it as part of their membership.

Meetings

73d Semiannual Convention of the SMPTE, Apr. 27–May 1, Hotel Statler, Los Angeles
National Association of Radio and Television Broadcasters, 7th Annual Conf., Apr. 28–May 1, Ambassador Hotel, Los Angeles
American Physical Society, Apr. 30–May 2, Washington, D.C.
Acoustical Society of America, May 7–9, Hotel Warwick, Philadelphia, Pa.

Society of Motion Picture and Television Engineers, Central Section Meeting, May 14, (tentative), Western Society of Engineers, Chicago

Society of Motion Picture and Television Engineers, Southwest Subsection, May 20, Dallas, Tex.

Society of Photographic Engineers, Third Annual Conference on Science in Photography and Photographic Instrumentation, May 20–22, U.S. Hotel Thayer, West Point, N.Y.

Society of Motion Picture and Television Engineers, Central Section Meeting, June 11, Geo. W. Colburn Laboratory, Chicago

American Physical Society, June 18–20, Rochester, N.Y.

American Institute of Electrical Engineers, Summer General Meeting, June 29–July 3, Atlantic City, N.J.

Biological Photographic Association, 23d Annual Meeting, Aug. 31–Sept. 3, Hotel Statler, Los Angeles, Calif.

Illuminating Engineering Society, National Technical Conference, Sept. 14–18, Hotel Commodore, New York, N.Y.

The Royal Photographic Society's Centenary, International Conference on the Science and Applications of Photography, Sept. 19–25, London, England

National Electronics Conference, 9th Annual Conference, Sept. 28–30, Hotel Sherman, Chicago

74th Semiannual Convention of the SMPTE, Oct. 4–9, Hotel Statler, New York

Audio Engineering Society, Fifth Annual Convention, Oct. 14–17, Hotel New Yorker, New York, N.Y.

Theatre Equipment and Supply Manufacturers' Association Convention (in conjunction with Theatre Equipment Dealers' Association and Theatre Owners of America), Oct. 31–Nov. 4, Conrad Hilton Hotel, Chicago, Ill.

Theatre Owners of America, Annual Convention and Trade Show, Nov. 1–5, Chicago, Ill.

National Electrical Manufacturers Association, Nov. 9–12, Haddon Hall Hotel, Atlantic City, N.J.

75th Semiannual Convention of the SMPTE, May 3–7, 1954 (next year), Hotel Statler, Washington, D.C.

76th Semiannual Convention of the SMPTE, Oct. 18–20, 1954 (next year), Ambassador Hotel, Los Angeles

Employment Service

Positions Available

Wanted: Cameraman-Director, young man free to travel, to work in Southern states. Must be able to show sample footage. Send résumé of experience and personal details in letter. Address replies to P.O. Box 1531, Louisville, Ky.

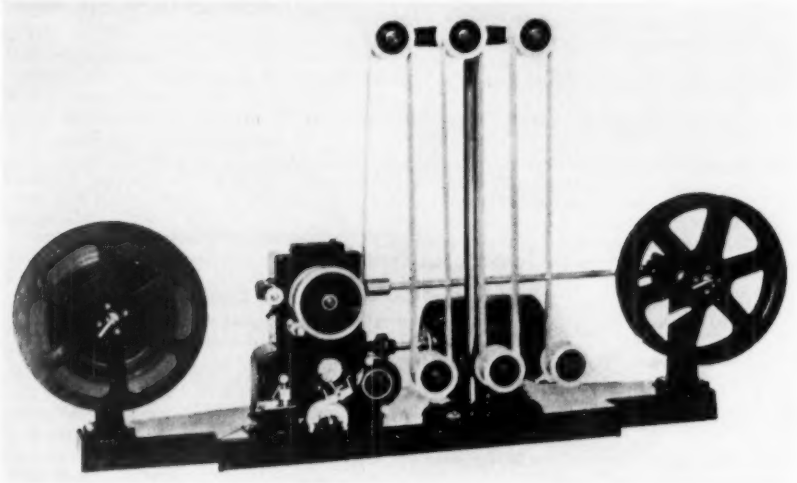
Career Opportunity in Midwest: for competent photographer and cinematographer experienced in 16mm production techniques to become permanently associated, as working partner, with well established, financially responsible company producing medical and scientific films exclusively. Must be under 40, of excellent character, good personality and educational background. Write, stating age, education, experience, history of employment, marital status, salary expected and where confidential correspondence can be addressed.—Mervin W. LaRue, Inc., 159 E. Chicago Ave., Chicago 11, Ill.

Position Wanted

Resigned Feb. 1 as gen. mgr., charge of production, large southern film studio. 15 yrs. experience as prod. mgr., editor and cameraman, 16mm and 35mm. Married, 37, college grad. References and résumé on request — Harlan H. Mendenhall, 5141 Bataan St., Houston, Tex.

New Products

Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products.

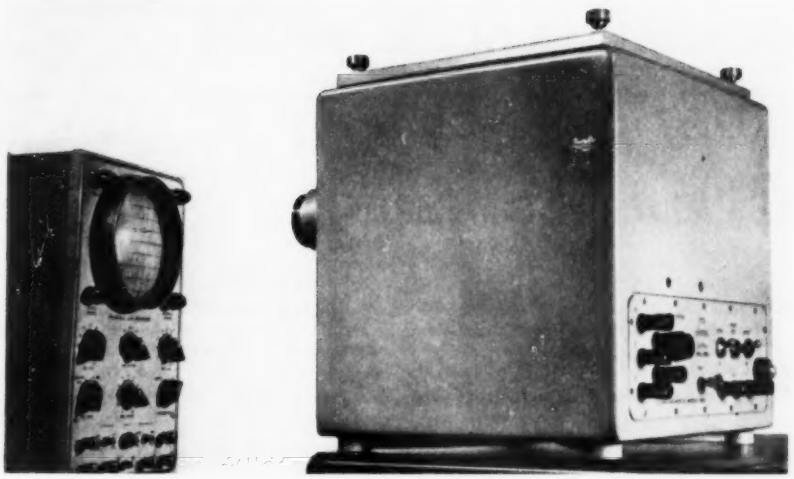


This Visible Edge-Numbering Machine for 35mm and 16mm has been marketed by S.O.S. Cinema Supply Corp., 602 W. 52d St., New York 19, N.Y. Film movement is nonintermittent. An automatically operated metal numbering block prints the footage number on the film at each revolution of the sprocket. The film is passed over a series of drying rollers and elevators before being rewound. The numbering block is kept clean by a combination of bristle brush and felt pad.

Film capacity is 2000 ft and printing speed is 50 ft/min. The 16mm model prints between the perforations only but the 35mm model can be supplied to print between the perforations or on the outside edge. The standard numbering block is for 6 figures, either with 2 handset and 4 automatic figure wheels, or with 3 handset and 3 automatic.

PHOTO-LAB-INDEX, 13th Lifetime Edition, has just been announced by Morgan & Lester, 101 Park Ave., New York 17, N.Y. It is presented as an enlarged, single-volume, loose-leaf duplex prong binder with 4-in. page capacity. It contains within its 1372 pp. a total of 24 sections of data on film, filters, illumination, photo papers, chemicals and many related aspects of the photographic field, and also sections called "Photo-Words" and "Television." The text and binder sell for $17.95, available at book and camera shops; a *Quarterly Supplement Service*, available only from the Publisher, costs $3.00 a year.

ECCO #1500 is an anti-static film cleaner and conditioner for use on motion-picture and strip film, produced and marketed by Electro-Chemical Products Corp., 60 Franklin St., East Orange, N.J. The manufacturer reports the use of a non-flammable solvent with an extremely low toxicity rating as a fast-drying film cleaner, and the extension of the cleaning of a negative to a cycle of only after 90 prints have been made.



The M.731 Universal Recording Camera, a cathode-ray oscilloscope recording camera which provides for still pictures, continuously moving film, and drum photography, has been announced by J. A. Maurer, Inc., Photographic Instrumentation Division, 37–01 — 31st St., Long Island City 1, N. Y. The camera is built by Southern Instruments Ltd., Surrey, England.

The continuously moving film mode of operation provides for speeds of from 0.4 to 100 in./sec, while the drum speeds are from 4 to 1200 in./sec. 35mm or 70mm film or paper, perforated or unperforated, may be used. The continuous-feed mode of operation provides for the exposure of lengths of film from a few inches to 25 ft, while for drum records a 50-ft capacity magazine supplies 20-in. film lengths cut to size by a built-in magazine knife. Twenty-five runs are possible without removal of the drum unit, the manipulation being done through black cloth sleeves set in the frame at the top of the camera.

The driving unit is a 6-v shunt-wound motor with a wide range of speeds obtained by voltage variation between 2 and 12 v. Electrical contacts are provided to trigger an external beam-suppression circuit on the oscilloscope, in order that the drum-type record may be made for only one revolution of the drum. A second electrical circuit permits the synchronization of an external event. A 3-in. $f/1.9$ lens is furnished, with others available. A sliding shutter is fixed to the lens tube mount to exclude ambient light. A slow-speed attachment which reduces film speed by a factor of 40 is available for use with the continuous-feed mechanism. The slowest speed available, therefore, is 0.01 in./sec.

Kodak Sonotrack coating is a new magnetic sound-track coating service now available from Eastman Kodak Co. for double-perforated 16mm film. Orders for this service will be accepted only through camera dealers. Work required to repair film to make it satisfactory for coating will be charged on the basis of the time consumed.

A new edition of the Society's Test Film Catalog is now available at no charge from the Society's headquarters. It covers 27 different test films, 16mm and 35mm, for use by theaters, service shops, factories and television stations. These test films have been developed by the SMPTE and the Motion Picture Research Council.

Committees of the Society

As of March 16, 1953

Administrative Committees

ADMISSIONS. *To pass upon all applications for membership, applications for transfer, and to review the Student and Associate membership list periodically for possible transfer to the Associate and Active grades, respectively. The duties of each committee are limited to applications and transfers originating in the geographic area covered.*

John G. Stott, *Chairman, East*, Du-Art Film Laboratories, 245 W. 55 St., New York 19, N.Y.

Harry C. Milholland — Norman F. Oakley — Ethan M. Stifle

Charles E. Phillimore, *Chairman, Central*, Bell & Howell Co., 7100 McCormick Rd., Chicago 45, Ill.

Geo. W. Colburn — C. E. Heppberger — Robert E. Lewis

Edward E. Reichard, *Chairman, West*, 13059 Dickens St., North Hollywood, Calif.

Fred G. Albin — Everett E. Griffith — William A. Mueller

BOARD OF EDITORS. *To pass upon the suitability of all material submitted for publication, or for presentation at conventions, and publish the* JOURNAL.

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C. H. Elmer	G. E. Matthews	J. H. Waddell
C. R. Fordyce	Pierre Mertz	D. R. White
L. D. Grignon	C. D. Miller	C. W. Wyckoff

EUROPEAN ADVISORY COMMITTEES. *To act as liaison between the general Society and European firms, individuals, and organizations interested in motion picture and television engineering. To report to the Society on such affairs in Europe, on new technical developments, and to assist the Papers Committee in soliciting papers for publication in the* JOURNAL.

I. D. Wratten, *Chairman (British Division)*, Kodak, Ltd., Kingsway, London, England

R. H. Cricks — W. M. Harcourt — L. Knopp — C. G. Mayer — A. W. Watkins

L. Didiée, *Chairman (Continental Division)*, Association Francaise des Ingénieurs et Techniciens du Cinéma, 92 Champs-Elysées, Paris (8e), France

R. Alla	J. Cordonnier	G. Mareschal
R. Bocquel	S. Feldman	M. Terrus
L. Busch	J. Fourrage	J. Vivié
M. Certes	C. V. Jarrett	M. Yvonnet

FELLOW AWARD. *To consider publications of Active members as candidates for elevation to Fellow, and to submit such nominations to the Board of Governors.*

Peter Mole, *Chairman*, Mole-Richardson Co., 941 N. Sycamore Ave., Hollywood 38, Calif.

Herbert Barnett	C. E. Heppberger	W. H. Offenhauser	V. C. Shaner
Frank E. Cahill	Henry Hood	E. S. Seeley	N. L. Simmons
John G. Frayne	Barton Kreuzer	John W. Servies	

HISTORICAL AND MUSEUM. *To collect facts and assemble data relating to the historical development of the motion picture and television industries, to encourage pioneers to place their work on record in the form of papers for publication in the* JOURNAL, *and to place in suitable depositories equipment pertaining to the industry.*

John B. McCullough, *Chairman*, Conservation Dept., Motion Picture Assn. of America, Inc., 28 W. 44 St., New York 18, N.Y.

(Under Organization)

HONORARY MEMBERSHIP. *To search diligently for candidates who through their basic inventions or outstanding accomplishments have contributed to the advancement of the motion picture industry and are thus worthy of becoming Honorary members of the Society.*

Fred T. Bowditch, *Chairman*, National Carbon Div., Box 6087, Cleveland 1, Ohio

F. E. Cahill Lloyd Thompson William C. Kunzmann Elmer Richardson

JOURNAL AWARD. *To recommend to the Board of Governors the author or authors of the most outstanding paper originally published in the* JOURNAL *during the preceding calendar year to receive the Society's Journal Award.*

F. J. Kolb, Jr., *Chairman*, Eastman Kodak Co., 343 State St., Rochester 4, N.Y.

Carlos H. Elmer Axel G. Jensen J. E. Volkmann W. Wallace Lozier

MEMBERSHIP. *To solicit new members and to arouse general interest in the activities of the Society and its publications.*

A. Raymond Gallo, General Chairman, Quigley Publications, 1270 Sixth Ave., New York 20, N.Y.
J. B. McCullough, Chairman, Motion Picture Association, 28 W. 44 St., New York 18, N.Y.
Col. S. R. Todd, Chairman, Bureau of Electrical Inspection, Room 707, City Hall, Chicago 2, Ill.
Henry M. Fisher, Vice-Chairman, DeVry Corporation, 1111 Armitage Ave., Chicago 14, Ill.
J. W. DuVall, Chairman, E. I. du Pont de Nemours & Co., 6656 Santa Monica Boulevard, Hollywood 38, Calif.
Forrest Jennings, Vice-Chairman, Color Reproduction Co., 7936 Santa Monica Blvd., Hollywood, Calif.
George Rutherford, Chairman, Foreign Membership Committee, Toronto Camera Exchange, 293 Church Street, Toronto, Ontario, Canada
R. D. King, Vice-Chairman, 35 Boorool Road, KEW E.5, Victoria, Australia

(Under Organization)

Member Delegates

V. D. Armstrong
H. C. Barr
P. E. Brigandi
H. P. Brueggemann
G. A. Chambers
R. W. Conant
J. W. Cummings
C. R. Daily
A. C. Davis
C. H. Elmer
C. R. Fordyce
D. C. Gilkeson
L. D. Grignon
G. R. Groves
Sol Halprin
R. N. Harmon
Bruce Howard
B. J. Howell
H. V. Jamieson
Culver Johnson
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W. C. Miller
G. C. Misener
C. C. Nopper
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G. F. Rackett
J. W. Servies
W. M. Sheahan
J. M. Sims
S. P. Solow
R. L. Sutton
J. E. Volkmann

NOMINATIONS. *To recommend nominations to the Board of Governors for annual election of officers and governors.*

Peter Mole, Chairman, Mole-Richardson Co., 941 N. Sycamore Ave., Hollywood 38, Calif.

Herbert Barnett
Harold C. Barr
G. A. Chambers
Carlos H. Elmer
W. B. Lodge
R. H. Ray
E. I. Sponable
R. E. Warn

PAPERS. *To solicit papers and provide the program for semiannual conventions, and make available to local sections for their meetings papers presented at national conventions.*

W. H. Rivers, *Chairman*, Eastman Kodak Co., 342 Madison Ave., New York 17, N.Y.
J. E. Aiken, *Vice-Chairman*, 116 N. Galveston St., Arlington 3, Va.
Skipwith W. Athey, *Vice-Chairman*, General Precision Laboratory, 15 South Moger Ave., Mt. Kisco, N.Y.
Geo. W. Colburn, *Vice-Chairman*, 164 N. Wacker Dr., Chicago 6, Ill.
G. G. Graham, *Vice-Chairman*, National Film Board of Canada, John St., Ottawa, Canada
Ralph E. Lovell, *Vice-Chairman*, National Broadcasting Co., Sunset and Vine, Hollywood 28, Calif.
John H. Waddell, *Vice-Chairman*, Wollensak Optical Co., 850 Hudson Ave., Rochester 21, N.Y.

James A. Anderson
Mark Armistead
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JOURNAL OF THE
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ENGINEERS

Magnetic Recording Materials

Experiences With Magna-Stripe

Magnetic Striping Techniques

Magnetic Striping by Laminating

Magnetic Tracks for Processed 16mm Film

Wear of Magnetic Heads

Dropouts in Magnetic Film

Measuring Surface Induction

Standardization Needs

THIS ISSUE IN TWO PARTS

Part I, April 1953 Journal

Part II, Symposium on Magnetic Striping of Film

APRIL 1953

Society of Motion Picture and Television Engineers
JOURNAL VOL. 60 APRIL 1953 NO. 4

Arthur C. Downes, Chairman, Board of Editors
Editor Victor H. Allen
William H. Rivers, Chairman, Papers Committee

Seven of these papers were presented as the "Symposium on Magnetic Striping of Film," on October 10, 1952, at the Society's Convention at Washington, D.C. One paper was presented on October 18, 1951, at the Society's Convention at Hollywood, Calif. The other paper in this Part of the *Journal* was presented on October 29, 1952, at the 4th Annual Convention of the Audio Engineering Society at New York, and is reprinted with permission from the *Proceedings of the Audio Engineering Society, Vol. 1, No. 1*, March 1953. The Symposium was under the chairmanship of Glenn L. Dimmick. The extensive service of editing the discussion, circulating it to all discussers and preparing final discussion copy has been done by R. T. Van Niman.

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Manufacture of Magnetic Recording Materials

By EDWARD SCHMIDT and ERNEST W. FRANCK

This paper describes in a general way the basic techniques employed in the manufacture of magnetic recording materials. Quarter-inch tape is first discussed, then full-width magnetic film and striping. Last is a brief prognostication of coming trends.

WHILE MUCH has been written on the art of magnetic recording, little has appeared on the methods and problems of manufacturing the recording media. Since the introduction of the first magnetic recorder in the 1890's, many types and forms of magnetic materials have been tried. Today, however, the bulk of all work in the field is on nonhomogeneous mediums, namely, those produced by the application of iron oxide powder to nonmagnetic base materials. This paper discusses the methods used by Reeves Soundcraft to produce plastic or paper base recording tape, and magnetic film products used in the motion picture field.

In a paper and demonstration at the Society's Convention at Lake Placid, in October 1950, we briefly reported on the development of 16mm striping.[1] The facilities used in this work have now been vastly expanded to include both 35mm and 8mm films. Two years of commercial experience have shown up a number of problems which are also discussed.

Presented on October 18, 1951, at the Society's Convention at Hollywood, by Edward Schmidt, who read the paper, and Ernest W. Franck, Magnetic Materials Div., Reeves Soundcraft Corp., Springdale, Conn.

(This paper was first received January 10, 1952, and in revised form on November 26, 1952.)

Base Materials

The German plastic tape products were coated on a vinyl type base material,[2] and had good tear and shrink characteristics but very poor temperature stability. Vinyl base cannot stand the normal rigors of heat in regular use. Calendered kraft paper has been used to some extent, but suffers from very low tear resistance and a poor signal-to-noise ratio due to paper's fibrous structure. The bulk of present day tape products is coated on cellulose acetate sheeting, 1.5 mils thick. This sheeting is manufactured in quantity as a standard item by three large American companies, Celanese Corp., Du Pont and Eastman Kodak Co., and is available in adequate quality and quantity. Since the moisture characteristics, swell and shrink

factors, and long term storage of di-acetate are not completely satisfactory, several new products are under study. One of these, Du Pont's "Mylar," a true plastic with vastly superior strength and stability characteristics is a step in the right direction. This product is now available on a limited basis for armed service use, and magnetic tape made using Mylar base has passed preliminary studies for several special army applications.

Pigment

The iron oxide used is precipitated out of solution, then subjected to a complicated heat treating cycle to produce controlled and desired magnetic properties. The particle size, approximately $\frac{1}{2}$ micron, is very closely controlled to produce an end product that is interchangeable with equivalent products of other manufacturers, and the size uniformity of particles is a very special chemical achievement.

Coating Mixture

The coating mixture is a magnetic paint, produced from the mixture of iron oxide pigment, a binder mixture and suitable solvents, which have no effect on the base composition. Its function is to hold the magnetic particles firmly in place on the base, with each pigment particle separate from the others. Since the pigment, or iron oxide, is the active ingredient, a high loading in respect to the binder is required. The process of dispersing the pigment in the carrier, or binder, is one of the most difficult from a manufacturing viewpoint and the most important of all production steps. The pigment particles are smaller than those used for paint and, in addition, are highly magnetic, therefore the tendency is to form agglomerates. Steel ball mills, where tremendous sheer stresses are generated by cascading hardened balls, are the best known apparatus for achieving good dispersion. Incomplete dispersion fails to produce the proper magnetic performance, impairs the high-frequency response, and results in low overall sensitivity.

Application of Coating Mixture to the Base

All Reeves Soundcraft tape is coated on specially designed machines on which the motion of the base through the machine rivals the steadiness of a good motion picture sound recorder. The coating is done by constant-head hoppers over a rigid support, not over a roller as was the German product. The plastic base receives a precoat before the pigment coating to provide good anchorage of the magnetic coating to the base. By achieving anchorage through the use of a precoat, no compromise with the best all-around physical properties of the coating material is necessary. The precoat also serves as an adequate barrier layer to minimize curl caused by different moisture absorption rates between the base and the coating; but, most important, it provides an ideal anchorage surface on the base for the previously mentioned high pigment loaded binder. The coating machine is also equipped with a continuous magnetic monitor. This allows constant checking of transverse and longitudinal uniformity of electrical output during coating. This equipment has a special recording head with a very wide gap, and monitors through the base side before the tape is completely dry. The wide-gap record head and the base side positioning permit the measurement of actual sensitivity of the tape, not the thickness of the coating. This equipment is virtually insensitive to small variations in spacing between the head and the coating and so is not affected by variation in base thickness.

Polish and Lubrication

Soundcraft tape is surface polished, by high-speed nylon brushes. Also at this station the surface is lubricated to minimize head wear. This process puts the

lubricant where it belongs, on the surface, rather than diluting the critical loading of the pigment mix and encouraging other problems of blush, etc., as humidity changes occur. Surface polishing improves the high-frequency response of unused tape and therefore decreases the frequently noted changes with actual running. At the time of polishing, the tape is given a rigorous visual inspection for coating defects.

Slitting and Testing

All slitting and testing equipment has been especially designed for the manufacture of recording tape. Weave and buckle in slitting have been minimized greatly. The slitter take-ups are equipped with constant-tension drives. The tension is adjusted to minimize the effect of seasonal weather conditions after the slitting process has been completed.

The test procedure and apparatus are designed so that the entire length of all tape produced is tested completely for uniformity, frequency response, etc.

Film Operations

Logically the application of magnetic coatings to motion picture film followed the use of such coatings on tape. The same red oxide pigment is used and so the same magnetic characteristics exist on $\frac{1}{4}$-in. tape and all film products. Hence, bias and erase conditions are standardized regardless of the end use of the product, whether the product be 35mm Magna-Stripe for professional use or 8mm amateur film. In the case of film, attention was paid to the physical properties of the coating to insure freedom from curl in all use conditions. A firm and well-anchored coating minimizes handling problems and surface friction. These are important factors because of the naturally high head pressures required in motion picture applications.

In the manufacture of magnetic film products, it was our conclusion that a better product would be achieved by using already slit and perforated film base, rather than coating in wide widths and slitting and perforating after coating. We believed it would be to our advantage to profit from the experience accumulated in this field by the film companies, who for over 30 years have been constantly striving to improve their slitting and perforating techniques. It was also our belief that the wear on punches and dies would be excessive due to the abrasive action of the oxides if we attempted to perforate after coating. Wear on film sprockets is avoided by not coating over the perforations.

In addition, we concluded that the control of coating uniformity over a 1 in. wide strip was immeasurably simpler than on 30- or 40-in. sheet. We also planned and have realized yields of approximately 100% as a result of using film already slit and perforated.

Our process is fundamentally an extrusion process rather than the dip-coating method employed by motion picture film manufacturers. It was found early that the dip-coating or roller-coating methods which worked on gelatinous photosensitive materials were not applicable to noncohesive mud-like magnetic coating mixtures.

Film Striping

Magna-Stripe was a logical step after the full-width film items, although historically striped-film development work started first. Striping presents some special and unique problems. Some of these are:

1. Very close dimensional tolerances;
2. Smooth, straight edges, so that an overlapping head will ride smoothly without amplitude modulation;
3. Flat and uniform top contour, to provide uniformity of output;
4. A balancing stripe—absolutely essential when handling any roll over 400 ft in length, or whenever any photosensitive product is coated;
5. High electrical output to produce a

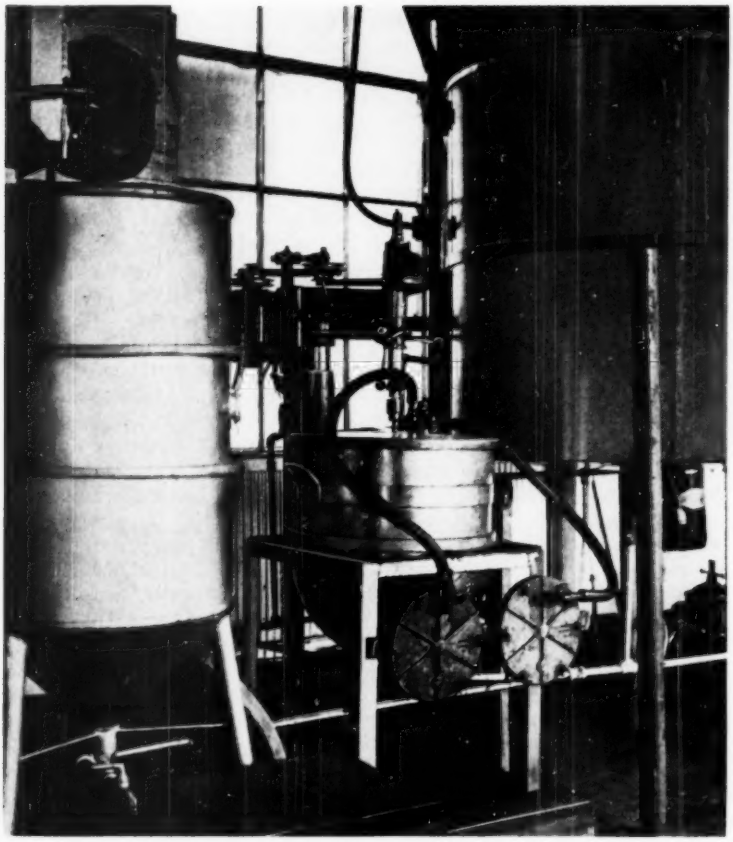

Fig. 1. Storage tank.

reasonable signal from the narrow stripes 20 or 25 mils wide;

6. It was important to develop a darkroom technique so that the process can be performed in total darkness on panchromatic or reversal original films;

7. It is necessary to avoid all emulsion scratches, etc.;

8. The stripe must not distort or curl the film under any use conditions of humidity or processing;

9. The stripe and its components must be inert photographically on all types of photosensitive emulsions and must be able to withstand any type of developing process without contaminating the processing solutions

To meet all of the foregoing performance characteristics for magnetic recording materials the following is a brief description of the apparatus and operations which we use in manufacturing.

Milling

The milling operation is probably the most important of any in the plant. Through the hatch in the center of the ball-mill drum are loaded carefully weighed and measured portions of oxide, solvent and binders. Running time may

vary considerably depending upon the size and diameter of a particular mill, its temperature rise, the type of oxides being milled, etc. Major progress has been made in improving this process to get better dispersion. Contrary to common belief, the tremendous sheering force of the steel balls in the ball mill has little, if any, effect on oxide particle sizes. Actually, the particle size range is already so small that it would be a very difficult, if not impossible, task to reduce it further by any mechanical means. This operation is purely a means of thoroughly dispersing and wetting the oxide particles.

All raw materials are purchased on a batch basis, and in the case of some critical components, samples are tested before shipment is authorized. A procedure for laboratory-scale milling has been developed which produces reliable advance information on stock lots. The remanence and coercive force of each batch of iron oxide pigment are determined and test coatings of laboratory-scale mixes are run completely through the process to provide uniformity of control. Each milled batch is test coated on the standard production equipment to determine magnetic and physical characteristics. After approval the mix is piped through commercial-type paper filters to an agitated storage tank. This is a sealed tank to prevent the evaporation of solvents and is constantly agitated to prevent the agglomeration of any particles, after the tedious milling operation just completed. Such a storage tank is shown in Fig. 1.

Coating

At the present time we have in operation several coating machines. The largest is capable of coating base materials up to 12 in. wide. This coater is seen in Fig. 2.

Here again the mix from the storage tanks is filtered to insure coating free of foreign matter or coagulated lumps. To the left, immediately after the feed roll, will be noted a coating head which is applying a very thin but precisely controlled layer of precoat. This is thoroughly dried before the base reaches the second coating station where the magnetic mixture is applied.

Here the base passes through a different type of coating head where a controlled thickness of the magnetic mixture is applied. The base is made to pass smoothly (without wrinkles) through this head so that a uniform layer is applied.

Drying

When the coated tape leaves the head, it is, of course, wet, just like freshly applied paint, and the rest of the machine is actually no more than a means of drying this wet coating by removal of the volatile solvents. Since only solvent removal, but no chemical change, is involved in the drying, there is no danger of over- or under-curing or oxidizing. The wet ribbon of magnetic material is now fed past controlled infrared lamps and space heaters and then into a more or less conventional-type drying cabinet. Final take-up of the complete 5000-ft roll is seen at the left in Fig. 3. During this operation every effort is made to eliminate all traces of dust and dirt. Air taken into the cabinet for drying purposes is thoroughly filtered beforehand. Inclusion of even minute particles of dust in the coating or on the surface will produce typical dropouts such as are seen on Brush high-speed charts. On these coaters, an adjustable record, reproduce and erase head assembly is mounted so as to sweep the full width of the base being coated. This monitors a test frequency through the base side of the tape and gives a rapid indication of the electrical output.

Polishing

Following the coating operation these wide rolls are buffed by high-speed nylon brushes to remove any traces of surface dirt and to burnish the actual coating to as smooth a surface as possible. The

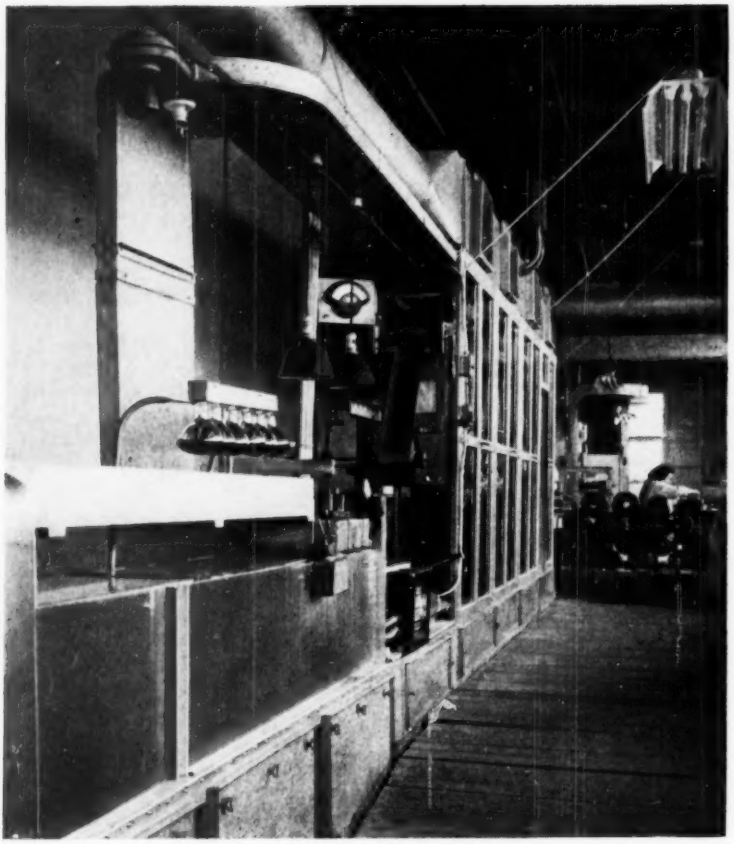

Fig. 2. Coating machine.

added smoothness attained by this operation can gain as much as 2 db in output level, particularly at high frequencies, because of better contact between the coating and the record-reproduce heads. This operation as well as the simultaneous application of the lubricant helps to eliminate the abrasive action of these coatings and reduce headwear.

Slitting

The next operation is the slitting of the wide rolls on rotary-knife slitting equipment. Such a machine is shown in Fig. 4.

While accuracy of slitting is of paramount importance, control of take-up tensions is even greater. From the manufacturers' standpoint, it would be desirable to spool under reasonably high tension to insure a tight, readily shippable and neat wind. From the ultimate users' viewpoint, however, such is not the case. The best currently manufactured plastic-base materials exhibit expansion and contraction characteristics of about 0.5% between the extremes of temperature and humidity normally encountered where tape is used. Even if the tape is originally wound under carefully controlled humidity and

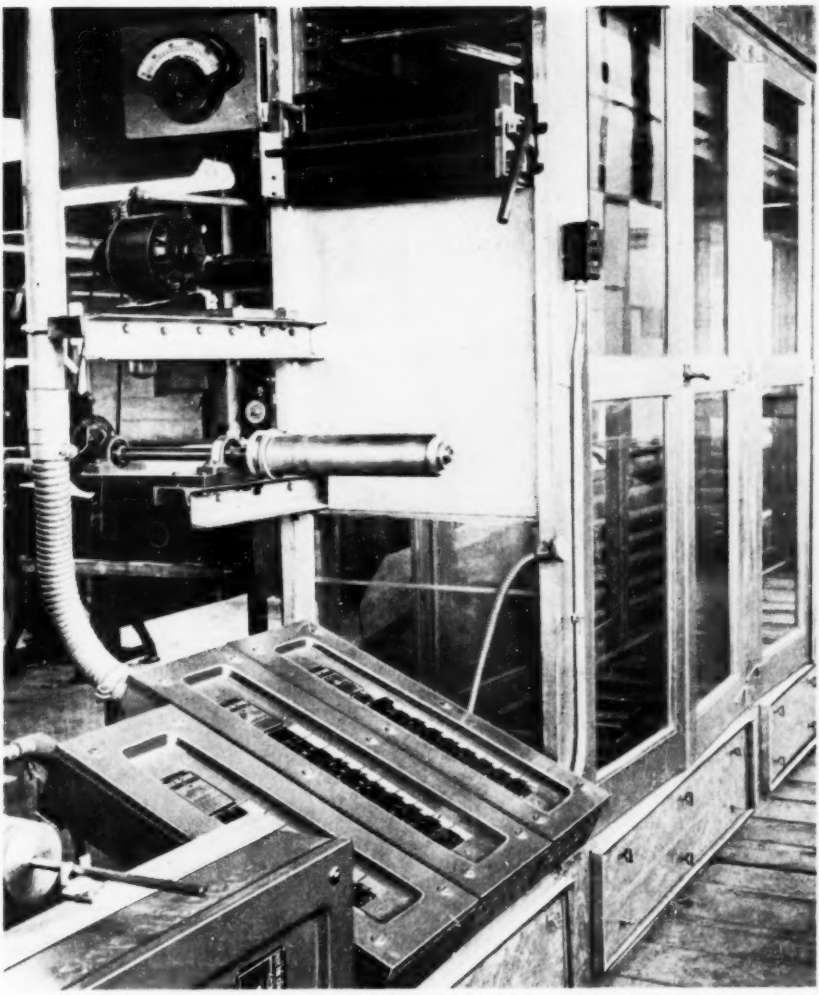

Fig. 3. Drying cabinet.

temperature conditions, that is no assurance that conditions during storage, shipment and use will be the same. Therefore, intentionally, we maintain only a small finished stock in our own warehouses and vary the winding tensions throughout the seasons. In the spring the tension is reduced in preparation for the summer months which, in the northern part of the country, bring high humidity and temperature. In the fall tension is increased. This, of course, is a poor answer to the problem, for no one can prophesy the ultimate conditions under which a tape may be used. Until the production of dimensionally stable base has been achieved, however, customers should allow tape to stabilize under

the conditions at which it will be used and then rewind at least once on the recorder to insure optimum tension for a particular piece of equipment. Adherence to this practice will greatly improve the performance of any $\frac{1}{4}$-in. magnetic tape product.

One complete $\frac{1}{4}$-in. tape from each roll of wide stock is fully tested on a special recorder. The 1000- and 10,000-cycle levels are recorded and an Esterline-Angus curve of the full length is run. Once a week, or whenever required by special conditions, sample distortion, bias, signal-to-noise and full frequency-response curves at varying bias conditions, intermodulation, print-through and the like are run.

Film Equipment

The production of magnetic film called for special coating machines, designed to include the special features which worked so well for $\frac{1}{4}$-in. magnetic tape.

Figure 5 is a general view of two of the film coaters. In this operation every effort is made to keep the air supplied to the drying cabinet and coating areas as clean as possible. This equipment is set up in an air-conditioned room, sealed from the rest of the plant. A positive static pressure is created after a triple-filter blower and conditioner device so that any dirt is blown out as the operators enter and leave the room. In addition, the pressure in the drying cabinets themselves is further elevated to insure dust elimination. The relatively high-viscosity oxide, binder and solvent mixture is delivered from the constant agitation and filter system seen under the nearest coater and is supplied to the coating hopper under constant head. Base thickness variations are automatically compensated for by special hopper design. Immediately following the coating hopper a bright inspection lamp is placed so that it shines through the film. This permits instantaneous inspection for any physical defect that may arise. From this point on, the coating is dried in a conventional motion picture film-drying cabinet where nothing contacts the coated side of the film until the finished reels are wound on the take-up. As will be noted, these are continuous-coating machines with front and rear elevator to permit splicing of new feed rolls and removal of completed ones. After the film leaves the drying cabinets, every roll is checked for its magnetic characteristics. Complete inspection is delayed for 24 hours to insure that the coating is thoroughly set. The equipment used for testing is a capstan-drive type of machine to insure that sprocket holes are not damaged before the film reaches the customer. The test procedure is to check the frequency response of each roll at 1000 and 10,000 cycles. At the beginning and end of each roll a high-speed Brush chart is run to check uniformity.

Following this inspection each roll is visually checked again on rewind equipment under a strong inspection lamp for evidence of dirt, scratches, etc.

Production of striped magnetic film (Magna-Stripe) is carried out on the same equipment as that used for full-width films. The difference is merely a change in the dimension of the hoppers which extrude the oxide mix. From the technical standpoint, stripes of any dimensions or any position on the base side of the film are feasible. All 35mm and 16mm striped films are supplied with a balancing stripe outside the sprocket holes. This has been found a necessity with all film lengths over a few hundred feet to prevent sloppy winding and consequent film damage. The standard thickness of these coatings, in both the recording stripe and balancing stripe, is approximately 0.0006 in. This added thickness is not so great as to cause any difficulties when the film is wound on standard 16mm reels holding up to 1200 ft in length as long as the balancing stripe is present. Stripes of any dimension from 15 mils and up are feasible. Location of the stripe presents no special problems.

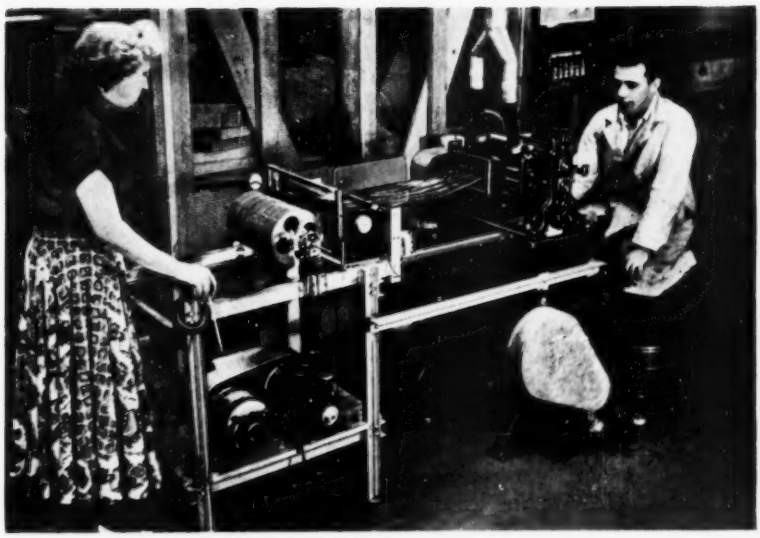

Fig. 4. Slitting equipment.

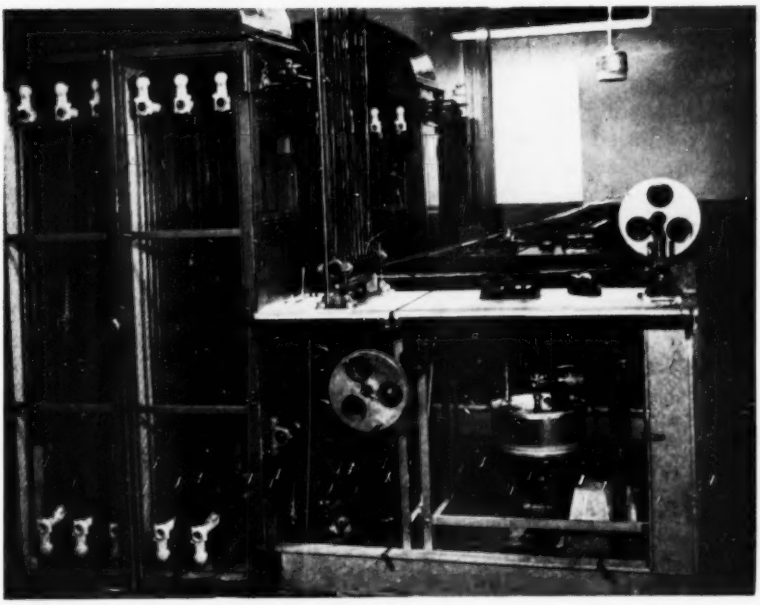

Fig. 5. General view of film coaters.

Present Trends and Future Outlook

In addition to previously mentioned new-type base supports, we must consider that in many other aspects the manufacture of magnetic recording materials is an infant industry. We are certain that the future will see a listing of product types comparable to that we now have in the photographic industry. Present-day magnetic tape is something of a compromise for use by professional and amateur users.

New oxides and binder combinations are under consideration which show marked decrease in mechanical friction on the heads Significant gains have already been made in control of print through, distortion and signal-to-noise, with further progress expected, perhaps in the form of a new professional-type tape. The variation of performance under different bias conditions will be reduced, giving a medium with greater bias latitude. Gains in minimizing the propensity of tape to attract dirt particles through static attraction will no doubt follow.

Through refinements of the various milling, mixing, filtering and coating steps, rapid improvement has been made in the past six months toward eliminating amplitude modulation, or high-frequency dropouts. This is especially interesting in the telemetering and calculating fields as well as in motion picture applications where large programs are dependent on the manufacture of substantially drop-out-free tape. Six months ago, standard tape showed defects at the rate of one part per 1000. Recent test coatings have improved to approximately one part per 100 million, roughly the target set by the calculating industry. It is important to remember here that calculating engineers find that standard tape products have a signal-to-noise ratio of 16 db rather than the 60 to 70 db found in audio work. In the calculating field, signal-to-noise is measured between the maximum noise pip and the minimum level of any one signal pulse in a full roll of tape. In this field, also, base quality, as determined by small surface pimples and dimples, is an important factor.

The future holds many new uses. Someday typesetting machines will be operated by magnetic tape. Punched cards could become obsolete. Any field requiring storage of data is an interesting application.

It is to be noted, however, that the advent of successful striping of 16mm film with magnetic coating has already made the synchronization of sound with picture a reality for a greater number of amateurs. Instruments for general use designed to record, reproduce and erase magnetic sound track, such as the RCA-400[3] magnetic projector and the Bell & Howell 202 are now available.

The impact of striped film is now beginning to be felt in the industrial, television and foreign-language fields. Promising work on the use of Magna-Stripe in motion picture production and editorial stages presages the day when full releases to the theater will be made magnetically. Magnetic sound on pictures, with all its obvious advantages over photographically recorded sound, is well on its way.

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Commercial Experiences With Magna-Stripe

By EDWARD SCHMIDT

Two years of commercial experience with magnetic striping have shown that successful striping demands film which will remain flat and undistorted under all conditions of climate and use. Some of the distortions to which all sound film is subject are here examined, with particular emphasis on the variations in centerline placement found on variable-area sound tracks. Particular problems of magnetic striping are analyzed and a set of standards for stripe placement suggested. Data were obtained from more than 2000 prints for all uses and categories, including amateur, professional, television and governmental agencies.

Reeves Soundcraft Corp. has been commercially "Magna-Striping" 16mm developed prints and positive photographic raw stock for almost two years. In that experience a number of correctible faults in the original film affecting the quality of the final product have been brought to our attention. It is our purpose to bring these problems, which in most cases affect either optical or magnetic sound, to the interested SMPTE units. In addition, there is considerable time pressure on committees of the Society to formulate standards for magnetic coatings and equipment, in order that this relatively new phase of our industry may grow without undue hazard of obsolescence and costly mistakes. Some of the data is directed toward possible solutions to some of the problems already discussed in engineering committee meetings, and some direct recommendations are made for standards, especially for the 50-mil or half stripe.

Presented on October 10, 1952 at the Society's Convention at Washington, D.C., by Edward Schmidt, Magnetic Materials Div., Reeves Soundcraft Corp., Springdale, Conn.

(This paper was received on November 7, 1952.)

Routine Tests

In many respects the Magna-Stripe service has given us an opportunity, perhaps unique in the industry, to observe certain aspects of print quality. Film is received from all sources, government, domestic and foreign; and is representative of all phases of our industry, from amateur baby pictures, to late feature releases. All prints received are given the following inspection and tests:

1. Physical inspection for damaged reels, film edge damage, etc.

2. Visual inspection, footage measurement, and tailing out of each print. A careful check is made for poor splices, damaged perforations, rips, tears or creases, or any other defect which will cause trouble on the coating machines.

3. The centerline position of variable-

area sound tracks is measured near the start, middle and end of each print to be half striped. An optical comparator is used and measurements are made with an accuracy of 0.002 in., although the recorded data from the three measurements is averaged and carried to the nearest 0.005 in. to accommodate weave factors.

4. Reinspection, and heading out by a second operator as a check on any omissions made in the first rewinding.

5. Visual inspection for curl, warped prints, curve cut, etc., which is made on a feed elevator in plain view of the coating machine operator.

6. Test and inspection of the finished product, heading out and remounting on the original reels.

Thus we see that each print is rewound four times by four different operators. Many of the typical defects seen on too many prints are avoidable, and have been considered in detail in previous papers and discussions. However they represent a hazard to the new magnetic phase of our industry, and it is our hope that interested and responsible engineers may welcome additional methods useful in correcting obvious faults in release prints.

Causes of Film Distortion

The June 1952 *Journal* contains an American Standard for 16mm film reels, PH22.11-1952. It specifies the flange and core concentricity as ±0.031 in. This does not cover the parallelism of the hub winding surfaces, but is in relation to the centerline of the hole for the spindles. The National Association of Radio and Television Broadcasters, and U.S. Government Interim Federal Specifications, W.T-61a, Navy Ships, 28 March 1952, for ¼ in. magnetic tape specifications include tight control of hub surface parallelism and concentricity of the winding surfaces. These specifications recognize the fact that cellulose acetate plastic base is subject to permanent deformation induced by cold flow. Any reel which because of poor hub design applies unequal stresses to the sides of the film can produce permanent long edge deformation. Numerous prints are deformed near the hub end. Occasional bad examples have a slit edge which wanders as much as ¼ in. in 12 in. from a straight edge when the film is laid flat. Obviously these long edges have a severe effect on the azimuth of any track, and it is surprising that some of the film will run through projectors. Defective prints of this nature are most extreme on film received from tropical areas, where humidity swelling adds to normal winding tension. The tolerable amount of hub diameter difference cannot be great, since the cumulative effect of winding pressures that start at the hub will carry distortion well into the center of some rolls. Measurements on reels which contained warped prints show 0.008 in., or greater, difference in diameter between one edge and the other.

We have often seen rolls of uncoated safety leader which are distorted throughout their length by plastic cold flow to a point where the film cannot be held flat. Careful measurements show less than 0.1 mil difference between one edge of the film and the other.

This tendency of film base to distort from unequal pressures on the two sides of the film is certainly a persuasive argument for the inclusion of a balance stripe in any set of standards prepared for striped magnetic film. As an example of the speed in which deformation occurs, 48-hour exposure at 90–95% R.H. (relative humidity) at a temperature of 90 F permanently ruined striped film lacking a balance stripe. The deformation of a balance-striped control wound under the same normal tension is hardly noticeable. It must be remembered that the magnetic stripe adds approximately 10% in total thickness, and this cumulative thickness difference applies distorting pressures directly on the area of the film which

must be kept flat for good head contact. The balance stripe tends to distribute the winding pressures equally on both sides of the film and improves storage stability of striped film.

We have prepared several film reels in which standard NARTB tape hubs are used for winding cores. These hubs are die cast and are given a surface truing operation in manufacture. Modern techniques of casting in either plastic or metal are sufficiently advanced so that the cost of manufacturing film reels with precision cores need not be prohibitive. The use of reels like these is imperative for prints destined for tropical areas, whether optical or magnetic.

Occasionally we see film with excessive curl, particularly in multilayer color stocks, very rarely in black-and-white films. A peculiarity exists here in that duplicate color prints are seldom if ever seriously curled.

Magnetic Sound Distortion

Since the factors mentioned so far contribute to the problem of maintaining uniform and continuous contact with the recording and reproduce heads it may be well to examine the mechanism of magnetic recording to see why flat and undistorted film is so important to this work. A magnetic recording signal is typically the audio signal superimposed on a supersonic bias frequency where the bias frequency is ideally greater than five times the highest audio frequency the equipment is designed to reproduce. A magnetic coating is only 5 or 6 ten thousandths of an inch thick. The field generated by the recording signal at the gap is geometrically concentrated in the top layers of the coating and penetrates only to a depth proportional to the width of the head gap. Thus while engineers have increased the high-frequency response of equipment by making heads with narrower gaps, the effective useful thickness of the coating is decreased. If the film, because of the typical base distortion previously described, is held away from intimate contact, the recording head cannot do its energizing work and a drop is observed in the reproduced signal level. Later in this *Journal* a paper by Ernest Franck will provide details on magnetic dropouts; his measurements show a combined record-reproduce loss on 35mm film of 31 db at 7000 cycles when the head is held only 0.0005 in. out of contact during record and reproduce. Therefore base distortions of the type described can make magnetic recordings unintelligible on equipment which has been designed without proper realization of the severity of base deformation sometimes encountered. Other equipment in which pressure rollers and special head mounts tend to force the film back to its original condition minimize the effect, but the fundamental cure will come from improved reel design, curl-free prints, and balanced magnetic stripes.

There is another property governing the uniformity of magnetic sound which has not been fully appreciated. All magnetic coatings made to date have small surface imperfections of lint or imbedded dirt, or small nodules of concentrated magnetic material which protrude from the normally flat surface of the coating. Any surface defect will cause a separation between the head and the magnetic coating and will result in so-called magnetic dropouts, or short term interruptions of the signal, which are quite noticeable to the ear. The fact that the magnetic coating on striped film is close to the edge exposes it to the accumulation of dirt after processing and during use. Therefore, Magna-Stripe coatings are made as hard and tough as possible to prevent grinding in and imbedding of handling dirt. A Magna-Stripe print can be cleansed with carbon tetrachloride without any damage.

If we measure the output uniformity of a magnetic signal on a high-speed pen motor recorder such as a Brush

BL222, at varying bias conditions we find that the higher bias currents markedly improve the uniformity of response. Thus a coating defect which caused a drop of 6 db when recorded at the point of peak bias, will be reduced to a 2-db dropout when the bias current is increased to a point where the output is 1.5 db below peak on a typical bias vs. output curve. Specific bias current values on our Westrex 1497 recorder are 23 to 33 ma. The distortion for the same output is unchanged over this range. There is a high-frequency loss caused by the higher bias of only 2 db at 7000 cycles compared to the 1000-cycle response, on 16mm film at 7.2 in./sec. This decrease in high frequency is certainly a cheap price to pay for the significant improvement in uniformity and freedom from dropouts obtainable by increasing bias current values.

Stripe Placement

The information obtained from striping a group of more than 2000 prints with a half, or 50-mil stripe has produced some interesting data on variable-area sound quality. A 50-mil stripe covers half of the original photographic track and is placed as close as possible to the centerline of the original optical track.

Each print is accurately measured on an optical comparator before striping so that the centerline position of the optical track is located in respect to its distance from the slit edge of the film. These measurements on a large group of prints disclose a misalignment of optical sound tracks which has an alarming influence on sound quality, whether the prints are striped or not.

ASA Z22.41-1946 defines the centerline of the sound track as 0.058 in. $\pm$0.002 in. from the unperforated edge of the film, and centers the 0.072-in. wide scanning beam of the reproducer on this 0.058-in. centerline. From these specifications it follows that any more than a 6-mil displacement of the centerline of a variable-area track will move part of the optical track outside of the scanning beam. Therefore, distortion and intermodulation effects are increased as the two-sided linearity of the variable-area track is lost. Measurements made at Reeves Sound Studios on a Westrex 16mm reproducer show that the distortion and intermodulation of variable-area track doubles for a 10-mil displacement from center; specifically from 1.6% to 2.5% 400-cycle distortion, and 4.8% to 9.0% for 2000/100-cycle intermodulation, for 100% signal. Naturally as signal amplitude is decreased and the track width narrows, these distortion effects are reduced. Therefore, it is difficult to place any limits, or define the point of centerline misplacement, at which an optical print is seriously damaged by poor centerline control.

However, when half of the track is to be covered with an opaque magnetic oxide we see that, unless the stripe is accurately located near the centerline of the optical print, the remaining half of the optical print will be seriously damaged. If the edge of the stripe protrudes past the centerline the opaque oxide will cover areas of low modulation and clip passages on standard bias galvanometer area tracks. This effect is less severe on dual bilateral tracks, as here peak modulation, rather than low modulation, is clipped. Peculiar distortion is introduced on any area track if the stripe does not cover enough of the width of the track.

Practical listening tests show that the stripe must be within 0.005 in. of the centerline to preserve reasonable optical quality. Occasionally we have found negative inserts where differences in centerline placement have been as great as 25 mils in a print. Film of this nature is difficult if not impossible to work with.

Still another difficulty is encountered when optical centerlines are misplaced. If the optical track is badly off center,

and the magnetic stripe is placed properly close to the centerline, poor optical sound may result because the remaining half of the optical track is no longer scanned by the reproducer beam. Therefore it is important that the control of centerline placement be good if satisfactory results are to be obtained from the half-stripe process. Listening tests of representative prints of varying centerline placement show that for best overall results the centerline should be controlled to ±0.005 in. Prints exceeding this tolerance begin to show optical deterioration, but it must be remembered that the magnetic quality is not affected if the stripe is located so that it is scanned by the record-reproduce head. In a group of 2396 prints half striped we find 1529 variable-area prints or 63.7% of the total with centerline positions more than 0.005 in. from the recommended location.

These measurements also showed 20.2% of the tracks were 50 mils or less, from the slit edge of film. 17.3% were 65 mils or more from the slit edge. The extremes were .35%, 35 mils from the slit edge or closer, and .5%, 80 mils or further. This data is in general accord with previous information already discussed by the SMPTE, and corroborates the long-felt need for better control of the optical process.

The above data influence the location of the 50-mil magnetic stripe and provide an answer to the grooving type of head wear which has been forecast as a serious problem in this work. In practice the striping equipment has been set up so that the operator sees a continuous enlargement of the optical track as it is coated. The coating hoppers are mounted on micrometer ways, indexed to an accurate dial gauge which is calibrated to the measurements made during inspection of the prints. In this fashion the operator can accurately move the stripe to accommodate different centerline placement, and if he is alert can sometimes catch the occasional interspliced negative of widely different centerline measurement.

The variations in optical track centerline positions have left us with no choice but to establish a practice of placing the stripe on the outside of 16mm film next to the slit edge on all prints having a centerline measurement of 60 mils or greater from the edge of the film, and to stripe on the picture half of the optical track when the centerline is 55 mils or closer to the slit edge. Reference to the previous data shows that 47.6% of the prints striped have the stripe placed on the picture side of the optical track and the balance on the slit edge of the film. Since the stripe can be placed on either side of the variable-density prints it is our practice to divide each lot of density prints into two groups and place the stripes on either side in equal amounts. Therefore, the danger and likelihood of any grooving type of head wear that might be anticipated is completely eliminated in practice.

Standards

With a procedure such as the above to follow, production standards for half-striped prints can be worked out along the following lines:

1. The stripe shall be 0.050 in. ±0.002 in. wide.

2. The centerline position of variable-area prints must be measured in two or more places to an accuracy of ±0.002 in.

3. The stripe shall be placed on the outside half of the photographic sound track when the centerline of the optical track is 0.060 in. or greater from the slit edge of the film. Guiding shall be done from the unperforated edge and the stripe placed on the picture side of the photographic track when the centerline measurement is 0.055 in. or closer to the slit edge.

4. In all cases the edge of magnetic stripe shall be placed within 0.005 in. of the centerline of variable-area sound tracks.

5. Variable-density prints shall be striped on either side of the optical track.

Discussion

Malcolm G. Townsley (Bell & Howell): Speaking as Chairman of the 16mm and 8mm Motion Pictures Committee, it seems to me that Mr. Schmidt has done an outstanding job here of proposing some standards which probably are badly needed in the Society, and I hope that he will officially transmit them to the Committee on 16mm and 8mm, or other appropriate committees, so that action can be started on them.

Mr. Schmidt: I'll be very happy to.

J. Kenneth Lewis (U.S. Navy, Bureau of Ships): You mentioned placing of the track on either the picture or the slit side of the optical track, but you have not mentioned which face of the film is used. I understand there's common practice there, but has a standard been established?

Mr. Schmidt: I don't know if there have been any standards accepted, but I believe Mr. Townsley could answer your question directly.

Mr. Townsley: The question of standardizing on which face of the film is to be striped has been covered for 100-mil track in a tentative standard which has been passed through the Magnetic Subcommittee and the Sound Committee and is now being balloted by the Standards Committee of the Society, and is expected to be advanced very shortly to an SMPTE Standard. Any standard which is written on 50-mil stripe will necessarily have to conform with the standard which is established for 100-mil stripe. The present standard, and the industry practice on which the standard is based, calls for the stripe to be on the surface of the film which is toward the projection lamp in normal operation of the projector.

William E. Cowles (General Electric Co.): Will the striping deteriorate or break down so as to scratch the film as it goes through the gate, and what effect would that have on the sound?

Mr. Schmidt: I don't believe there is any deterioration of the striping that would scratch the film in the gate. A properly made stripe has a very hard, tough surface, and resists serious mechanical abuse. You can take 400-mesh carborundum grit and roll it onto a proper stripe, and then wipe that carborundum dust free from the stripe leaving no embedded particles, or very few. Therefore with this type of dirt resistivity in the product, abrasive types of wear which you might expect from accumulated dirt and other problems of that nature should be minimized.

Mr. Lewis: When you place your stripe on the side of the track which is associated with the picture, have you any data which indicate the degree of wear the stripe may cause on the guide rail which is used at the optical aperture for the picture projection and which in most projectors is generally a very narrow surface where unit pressure may be quite high?

Mr. Schmidt: We have no direct data, but I believe Mr. Del Valle of RCA has accumulated some specific wear data which he is to present later on this afternoon in his paper.

Paul Ireland (EDL Company): Did you state that the guiding was sometimes done from the perforated edge of the film?

Mr. Schmidt: No, the guiding for the placement of the 50-mil stripe is done from the slit edge of the film.

Paul Peters (Engineer Research and Development Laboratories, Fort Belvoir): In regard to the standard defining the placement of the track toward the lamp in 16mm work, for contact Kodachrome dupe you have one emulsion position. On a release positive from a dupe negative, with reversal original, you have an opposite facing of the emulsion. To conform to the standard you would coat either emulsion side or base side. Now in printing, say, a black-and-white from a dupe negative, you are coating on the emulsion side of unprocessed raw stock. What effect will processing have toward deforming the magnetic striping after it is processed and dried?

Mr. Schmidt: We are not coating any photographic raw stock on the emulsion side. We resist the idea and hesitate to coat developed prints on the emulsion side, but are doing it as a routine practice with a warning to our customers that the permanence of the stripe is not warranted, as a rapid excursion in humidity conditions will affect the bond on any striped material we have seen to date. Photographic gelatin can be fickle stuff and does not always react the same in respect to swelling and shrinkage with moisture changes, so seemingly good results that are obtained

on one print are impossible to get on the next one that you try.

Mr. Peters: All of the commercial projectors I've seen have a single head playing either one side or the other. Now in that instance it would have to be standardized for either Kodachrome dupe, contact, or else you'd have to make optical prints from your black-and-white.

Mr. Schmidt: I don't know whether two years of data is typical of emulsion position distribution, but we find less than 3% of work we receive is in the nonstandard emulsion position.

Otto Kornei (Brush Development Company): What is your explanation of the beneficial effect of increased bias on dropouts?

Mr. Schmidt: What is probably happening there is that under low bias conditions, the high-frequency bias current is restricted and confined, and is doing the principal amount of its work in the top layers of the coating. This is certainly especially true of the higher-frequency audio signal components, which are confined and held under low-bias conditions near the top of the coating. However, as you increase the bias, you effectively begin to energize more of the coating thickness and put more of your signal down into the body of the coating so that the same physical contact interruption between the head and the film has a lesser signal interruption effect on record.

George Lewin (Signal Corps Photographic Center): I'd like to make one observation and then also ask a question. Regarding the improvement due to increased bias, I would like to confirm Mr. Schmidt's findings. We made similar tests quite some time ago, making oscillographic recordings of the steadiness of contact. It is definitely true that an increase in bias will give you quite an improvement.

The question concerns half stripes. You did mention that the most critical type of track to put a half stripe on is the bias galvanometer type, with a bias line down the center of the track. It's been our experience, and I'd like to get your opinion as to whether your listening tests have confirmed it, that it's very preferable to play safe, and make the magnetic track actually have some clearance with respect to the centerline, rather than try to follow the centerline exactly.

Mr. Schmidt: We have learned to do that in practice. We try to be certain that the bias septum is never covered on a bias galvanometer track, but occasionally you run into 5- or 6-mil misplacements between two negative reels spliced together in the same print, and if the coating operator isn't actually watching what's happening at the particular moment the negative splice passes, you may find occasional trouble. I have not heard of many complaints on the process, however. As a matter of fact, the only complaint that we have ever had on a 50-mil stripe was one in which the photographic track no longer sounded any good, but the magnetic track was fine. There was only one thing wrong with that print, and that was that the centerline of the original photographic track, which was a bias galvanometer type track as I recall, was about 75 mils from the slit edge of the film, which left nothing of the original track for the scanning beam to reproduce on playback, once half of the photographic track was covered.

Magnetic Striping Techniques and Characteristics

By B. L. KASPIN, A. ROBERTS, JR., HARRY ROBBINS and R. L. POWERS

This paper describes the progress made at the Bell & Howell Co. since 1947 in the development of a magnetic sound track for motion picture film: methods of sound-track application; compositions tested; testing procedures; chemical, mechanical, and electrical results obtained; and standards adopted.

THE FIRST ATTEMPTS at Bell & Howell to apply a magnetic sound track to motion picture film were made in 1947. Since that time work has been going on more or less continuously to improve the nature, characteristics and application of this track. A set of qualitative goals and standards was initially established, to be made precise and quantitative as experience was accumulated. These were originally as follows:

(*1*) *Physical:* The track must be tough, flexible, smooth, within dimensional tolerances and, in general, undamaged by any treatment that would not damage the film itself (e.g. heat, humidity, flexing).

(*2*) *Chemical:* No deleterious effects must be produced by any substance which might normally come into contact with the film during cleaning (carbon tetrachloride, trichlorethylene, alcohol, etc.) or during projection (lubricating oil). Also, the track must adhere well to every common type of film (cellulose acetate, triacetate, acetate-propionate, etc.), both to the base side and to the emulsion.

(*3*) *Performance:* The output level from the magnetic track must be satisfactorily uniform throughout the reel length, and a standard level must be closely maintained in all coatings. The bias-output and frequency-response characteristics must be reproducible to assure compatibility with bias supply and equalization characteristics of projection equipment. Dynamic range, noise level, and harmonic distortion shall be acceptable under current standards for quality optical sound systems.

Presented on October 10, 1952, at the Society's Convention at Washington, D.C., by B. L. Kaspin, who presented the paper, A. Roberts, Jr., Harry Robbins and R. L. Powers, Bell & Howell Co., 7100 McCormick Rd., Chicago 45.
(This paper was received on October 27, 1952.)

Testing of Physical and Chemical Properties

In order to check new magnetic formulations for conformity to the afore-

mentioned physical and chemical standards, the following procedures were devised. A uniform layer of the composition in question is first applied to the entire surface of an 8-in. length of film by means of a special doctor blade type of paint film applicator. Double surface pressure sensitive tape is used to hold the film flat on a glass plate during the application. After an appropriate, short drying period (a few minutes) the coated film is lifted from the tape and permitted to dry further at room conditions for about 16 hr.

Sections of the coated surface are then vigorously swabbed with cotton pads moistened with the solvents (carbon tetrachloride, etc.) previously mentioned. A coating is judged satisfactorily solvent-resistant only if the pads remain entirely or very nearly entirely, free from coloring by the magnetic pigment after this treatment.

The toughness and adhesion of the magnetic layer are then crudely checked by attempting to scratch or remove it with the fingernail after a break in the surface continuity has been made with a steel point. If the material looks promising, additional coated film strips are subjected to a series of accelerated aging and humidity cycles, each consisting of a 16-hr exposure to 140 F followed by 8 hr at room temperature and 92% relative humidity. After six such cycles the film is permitted to come to equilibrium with room conditions for 16 hr.

A flexing procedure follows next in which the film is pulled to and fro (180° bend, 20 times) around a $\frac{1}{4}$-in. diameter metal rod under a tension of about 2 lb. The magnetic coating is on the outer surface during this procedure. The coating is then checked. If, at this stage, it is impossible to remove any of the coating by means of the fingernail test the coating is rated as excellent for adhesion and toughness. If material can be removed but only with considerable difficulty the rating is good.

A further corroborative test for adhesion usually performed consisted of first pressing a piece of Scotch Tape firmly down upon the coated surface and after a few minutes, vigorously yanking it off. None, or very little, of the magnetic material must have transferred to the tape. If all of these tests have been successfully passed, a length of film that has been striped (full track) with the regular applicator is then subjected to the same procedure. No data are available concerning the correlation between the accelerated aging and humidity conditioning and actual field exposure. The procedure, however, is considered sufficiently severe to correspond to long and hard use.

One unanticipated problem that arose early in the investigation was that of film curl. In practically all cases the application of sound-track material to film caused some degree of curl to develop either immediately or after some time. In all cases the curl was: (1) concave towards the sound-track side, (2) more severe on base sound track than on emulsion and (3) serious enough to be objectionable only on full track (100 mils). In order to evaluate the effects of different factors (humidity, magnetic composition, etc.) in causing this condition, a method of measuring curl was required and the following was developed.

Lengths of film that had been coated and dried as described in a previous paragraph were cut crosswise into $\frac{1}{8}$-in. wide strips and the strips placed on the horizontal stage of a Wilder Micro Projector. The distance X (Fig. 1) was then measured on the projected image. From X the angle of curl α can be obtained as shown. The equation given does not permit the ready direct computation of α. Instead, arbitrary values are assigned to the radius of curvature R, corresponding values of α and X are computed, and a graph is constructed of α as a function of X (Fig. 2).

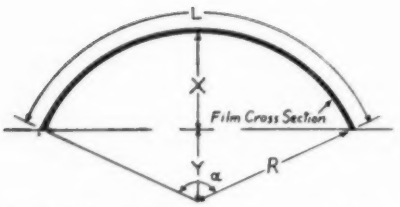

Fig. 1. Arrangement for measuring curl.

$$\alpha \text{ (radians)} = \frac{L}{R}$$

$$L = 0.630 \text{ in. (film width)}$$

$$R = X + Y = X + R \cos \frac{L}{2R}$$

$$R\left(1 - \cos \frac{L}{2R}\right) = X$$

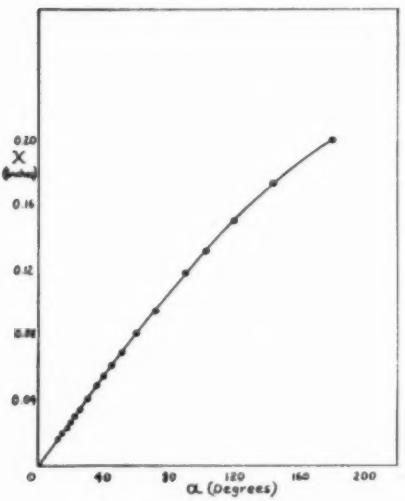

Fig. 2. Film curl data.

$$R\left(1 - \cos \frac{L}{2R}\right) = X \qquad \frac{L}{R} = \alpha$$

R	X	α
0.20 in.	0.200 in.	180°
0.30 in.	0.150 in.	120°
0.35 in.	0.132 in.	103°
0.40 in.	0.119 in.	90°
0.50 in.	0.095 in.	72°
0.60 in.	0.0805 in.	60°
0.70 in.	0.0692 in.	51.5°
0.80 in.	0.0608 in.	45°
0.90 in.	0.0540 in.	40°
1.00 in.	0.0490 in.	36°
1.20 in.	0.0408 in.	30°
1.40 in.	0.0350 in.	25.7°
1.60 in.	0.0304 in.	22.5°
1.80 in.	0.0270 in.	20.0°
2.00 in.	0.0240 in.	18.0°
2.50 in.	0.0200 in.	14.4°
3.00 in.	0.0165 in.	12.0°

Another difficulty considered was the possible embrittlement of film produced by application of magnetic sound track. To check this, full-width sound track was applied in the standard manner to many different types of film and then tested using a Pfund Tester in accordance with ASA Z38.3.2-1945. Film was tested, striped and unstriped, heat aged (72 hr at 212 F followed by 16 hr at room temperature and 65% relative humidity) and unaged, and with and without hot calender treatment of the magnetic stripe. The latter treatment, to be described more fully later, was found to produce a much smoother track resulting in a slight decrease in head wear and a slight increase (about 2 db on some films) of output at the higher frequencies.

Film Curl

Tables I and II show the effects of coating thickness and film humidity conditioning prior to coating on the degree of film curl obtained, with one particular coating formulation bearing the lab number 105. All values given are averages of several determinations. The values of "Thickness of dry coat" are of only limited reliability, especially in the case of severely curled films, since they were measured with a micrometer and the readings are dependent to a great extent upon the pressure required to flatten the film. All values of α given are corrected for the original curl of the uncoated film. In general the data indicate that: (1) the degree of film curl increases rapidly with coating thickness; and (2) films of excessively

Table I. Coating Thickness as a Factor Affecting Film Curl

(Striping composition #105; Film, Eastman Type 5302, triacetate)

Emulsion coating			Base coating		
Doctor blade setting	Thickness of dry coat	Curl	Doctor blade setting	Thickness of dry coat	Curl
0.003 in.	0.0001 in.	<3°	0.003 in.	0.0003 in.	33°
0.006 in.	0.0005 in.	<3°	0.006 in.	0.0009 in.	110°
0.009 in.	0.0008 in.	37°	0.009 in.	0.0012 in.	>300°

Table II. Humidity Condition Prior to Coating as a Factor Affecting Film Curl

(Striping composition #105; Film, Eastman Type 5302, triacetate)

	Emulsion coating			Base coating		
Relative humidity	Doctor blade setting	Thickness of dry coat	Curl	Doctor blade setting	Thickness of dry coat	Curl
20%	0.008 in.	0.0007 in.	33°	0.008 in.	0.0013 in.	180°
52%	0.008 in.	0.0007 in.	31°	0.008 in.	0.0012 in.	110°
65%	0.008 in.	0.0008 in.	46°	0.008 in.	0.0012 in.	117°
97%	0.008 in.	0.0012 in.	118°	0.008 in.	0.0013 in.	>300°

high- or low-moisture content tend to curl most severely (particularly when base-side coated). Moderate moisture content in the range corresponding to equilibrium with perhaps 40 to 60% relative humidity seems to be optimum. The data also indicate that composition #105 would be unsuitable for use on base because of excessive curl, and that different compositions would have to be tried with a view towards minimizing curl.

The effects of differences in the type of film upon curl produced are shown in Table III. The fact that the triacetate film showed the most curl (i.e. with composition #105) was quite unexpected since this material is, in general, the most solvent-resistant of the film-base materials. With composition #125, however, our current base composition, the effects are quite different. In any case differences found in the behavior of different film-base materials were not very large, being, in fact, almost within experimental error.

Film Embrittlement

The test method employed here was that described in ASA Z38.3.2-1945. The first number of the pairs given (Table IV) represents the number of folds required to produce the first definite break in the film; the second number represents the folds required to completely divide the film into two parts. Each figure is the average of four determinations. The reproducibility of individual determinations is rather poor. The data indicate that whereas in some cases, the application of a magnetic sound track tended to slightly embrittle the film, the effect was small. Film which would initially conform to the ASA requirements for flexibility of "Film for Permanent Records" would usually still do so after striping and hot calendering. Incidentally, the data

Table III. Nature of Film as a Factor Affecting Film Curl

Film	Emulsion coating: Doctor blade setting	Emulsion coating: Thickness of dry coat	Emulsion coating: Curl	Base coating: Doctor blade setting	Base coating: Thickness of dry coat	Base coating: Curl
(Striping composition #105)						
Du Pont, Type 301 (acetate)	0.006 in.	0.0007 in.	9°	0.006 in.	0.0007 in.	51°
Du Pont, Type 825 (triacetate)	0.006 in.	0.0007 in.	17°	0.006 in.	0.0008 in.	68°
Eastman Kodachrome Type 5363 (acetate - propionate)	0.006 in.	0.0006 in.	10°	0.006 in.	0.0008 in.	64°
(Striping composition #125 — for base only)						
Du Pont, Type 301				0.006 in.	0.0007 in.	11.5°
Du Pont, Type 825				0.006 in.	0.0007 in.	8.7°
Eastman Kodachrome, Type 5363				0.006 in.	0.0007 in.	3.0°

indicate quite clearly the superiority in this respect of "triacetate" or "high acetyl" film to the more hydrolyzed ordinary cellulose acetate.

Striping Formulations

The problems in formulating striping compositions differ in several ways from those in formulating pigmented lacquers in general. In addition to the requirements mentioned of solvent resistance, low curl-producing tendencies, etc., maximum ratio of magnetic pigment to binder is also essential. Generally speaking, pigment concentrations of 70–75% based upon total solids content afford the best compromise between physical properties, which fall off rapidly at higher concentrations, and signal output which decreases as the concentration falls below 70%.

Optimum values of such physical properties as viscosity, drying rate, etc., depend obviously upon the method of striping used. With the current Bell & Howell striping equipment, a viscosity of 30 ± 2 sec at 70 F (Zahn No. 3 Viscosity Cup), plus a stripe drying rate of 30 sec at room conditions, is satisfactory. With such material and equipment it was found that the stripe thickness obtained was constant over a large range of striping speeds. Also, the high drying rate permitted the film to be rolled up within one minute after striping.

In spite of extensive experimentation with different resins, plasticizers and solvents, the only formulas developed which gave good adhesion to the emulsion side of the film while fulfilling all other requirements of a satisfactory striping material, were those containing acetic acid. Acetic acid, however, when applied to the film base, was one of the worst offenders in causing curl. It was necessary, therefore, to develop different formulations for striping emulsion and base.

Curl is caused by many factors but the most important one seems to be solvent attack on the film base. For this reason active solvents such as acetone, ethyl acetate, methylene chloride,

Table IV. Film Flexibility by Pfund Test (ASA Z38.3.2—1945)

						Heat Aged				
	Unstriped film	Striped emulsion	Striped base	Striped, hot cal. emulsion	Striped, hot cal. base	Unstriped film	Striped emulsion	Striped base	Striped, hot cal. emulsion	Striped, hot cal. base
B & H Panchro (experimental)	22–26	20–30	19–30	18–24	15–23	19–22	18–22	21–28	14–19	16–20
Du Pont Type 301 (acetate)	17–23	16–27	14–24	14–19	12–18	14–23	17–23	15–23	12–17	13–18
Du Pont Type 600 (acetate)	10–19	10–23	15–25	14–16	12–18	12–19	11–21	11–19	14–19	10–16
Du Pont Type 825 (triacetate)	26–33	23–39	28–41	22–32	20–32	30–35	26–34	38–49	25–32	19–28
Du Pont Type 901 (triacetate)	21–28	20–23	25–31	18–26	20–26	20–27	23–32	25–33	16–23	18–26
Eastman Kodachrome, Type 5363	15–19	19–22	18–23	12–17	14–19	13–16	16–18	14–19	14–17	16–18
Eastman, Type 5302 (triacetate (older))	24–34			23–30	23–28				21–29	22–29
Eastman, Type 5302 (triacetate)	24–33	29–34	21–25	20–28	20–28	25–31	30–32	27–34	20–25	19–24
Ansco Color, Type 235	16–23			15–23		14–22			14–19	14–18
Ansco Hypan (reversible)	33–44	27–39	30–37	28–35	31–38	27–34	26–33	28–34	24–33	22–31

Table V. Film Forming Resins

Cellulose acetate	Too-strong solvents required; no advantages over nitrocellulose in physical properties or adhesion.
Ethyl cellulose	Good film former; no adhesion; soluble in trichlorethylene and carbon tetrachloride.
Vinyl chloride–acetate copolymer	Fair adhesion; tend to gel with iron pigments; too soluble in trichlorethylene and carbon tetrachloride.
Acryloids	Available only in solution of strong solvents; curl is a problem.
	Fair adhesion; can be blended with nitrocellulose to reduce solubility; considerable tendency for crazing on emulsion side.
Water emulsions	Slow drying rate; soluble in trichlorethylene and carbon tetrachloride; tends to foam excessively; susceptible to moisture; poor adhesion to base side.
Vinyl acetate	Similar to acryloids in results.
Chlorinated rubber	Hard brittle film; poor adhesion
Acrylonitrile rubber	Films are soft and flexible, have considerable friction to sliding over soundhead; soluble in trichlorethylene and carbon tetrachloride; fair adhesion.

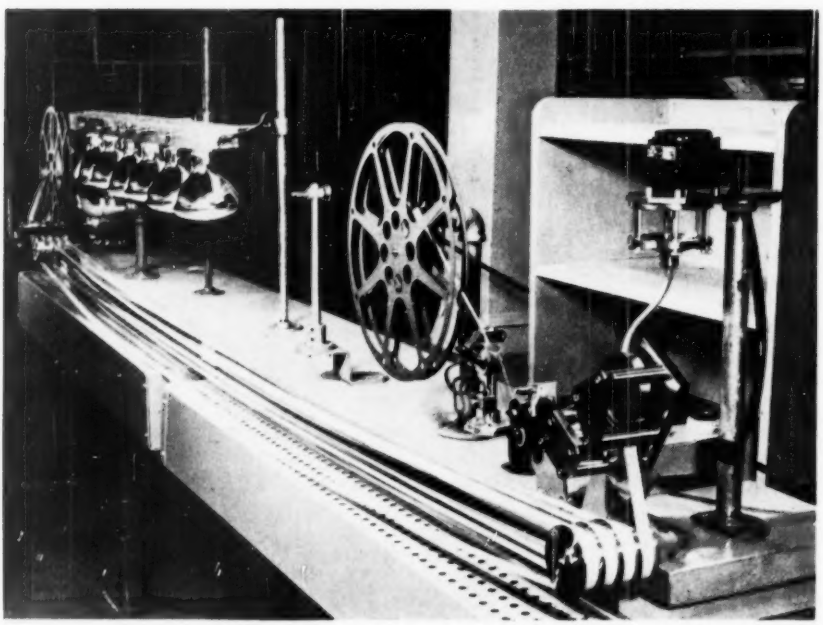

Fig. 3. The laboratory unit consisting of reservoir, applicator, drying rack, heated calender and take-up mechanism.

Table VI. Magnetic Striping Compositions

Base		Emulsion	
Solids	35% by weight	Solids	33.3%
Solvents	65%	Solvents	66.7%
Solids		*Solids*	
R.S. nitrocellulose (½ sec)	19.4%	R.S. nitrocellulose (½ sec)	16.7%
Maleic resin (Arochem 520)	4.8	R.S. nitrocellulose (6 sec)	3.3
Castor oil	5.8	Maleic resin	4.0
Magnetic pigment (IRN-110)	70.0	Dioctyl phthallate	6.0
		Magnetic pigment (IRN-110)	70.0
Solvents		*Solvents*	
Sec. butyl acetate	44.0	Sec. butyl acetate	33.3
Isopropyl alcohol	8.0	Ethyl acetate	34.2
Methyl cellosolve acetate	8.0	Isopropyl alcohol	12.5
Toluene	40.0	Acetic acid (glacial)	20.0

etc., must be avoided or used very sparingly. It is, however, not possible to completely avoid active solvents since some attack on the film base is necessary to secure adequate adhesion.

The problem of adhesion vs. curl is further complicated by the existence of film bases of different compositions on the market. Films made from cellulose diacetate stock are readily soluble in many solvents, whereas higher acetylated bases, which are becoming more popular, are difficultly soluble in only a comparatively few solvents. For this reason lacquer formulations that give satisfactory adhesion to diacetate may fail to adhere to triacetate, and those that adhere well to the latter may cause curl on the former. We have found that the presence of a small amount of methyl cellosolve acetate in the base-striping formula produced satisfactory adhesion with a minimum of curl.

Among the different resins tested for use as "film formers" in the striping compositions, only cellulose nitrate appeared satisfactory. The addition of some maleic resin to this material enhanced the adhesion and also tended to produce a faster solvent release, enabling a shorter drying time.

Table V lists the other resins tested and their apparent shortcomings for this use.

The current formulas for base and emulsion striping compositions are shown in Table VI.

The magnetic pigment IRN-110 is obtained from C. K. Williams & Co., and is the red γ-Fe_2O_3 form of iron oxide that is generally used in the industry.

Preparation of either formula consists merely of placing all the ingredients in a ball mill and grinding for 24–48 hr to effect complete dispersion. The mix is strained through 200-mesh silk bolting cloth before bottling.

Shelf life of the base composition seems to be indefinite though the material must be adequately mixed to redisperse the pigment before using. The emulsion composition tends to decrease in viscosity on long standing at room temperature. It should be used within a few weeks after preparation or kept refrigerated to extend this period.

Striping Procedure and Apparatus

In the first attempts to stripe motion picture film at Bell & Howell, a rather crude laboratory set-up was used. This consisted of a constant speed take-up, a Gits oiler equipped with a tubular orifice mounted on an adjustable frame

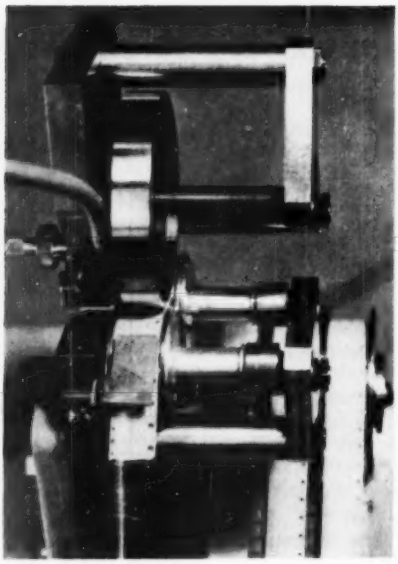

Fig. 4. The applicator head.

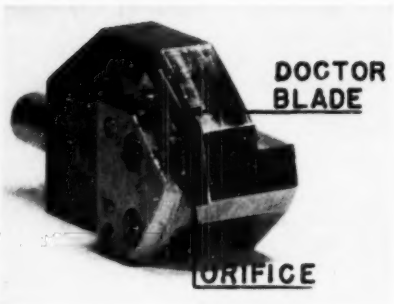

Fig. 5. Orifice and doctor blade.

and a drying rack. A calender was added to improve the surface of the stripe. The film was passed under the orifice that allowed a stream of magnetic material to flow out onto the surface between the perforations and the edge of the film. The present method of applying Soundstripe is essentially a highly refined version of the original arrangement.

The production of Soundstripe requires a unit capable of holding close tolerances. Present striping speeds of from 30 to 60 fpm necessitate a rigidly constructed applicator head containing precision guide rollers to properly align the film and an applicator preadjusted to provide a stripe of proper thickness.

Figure 3 shows the complete laboratory unit as used by Bell & Howell, consisting of reservoir, applicator, drying rack, heated calender and take-up mechanism. The magnetic material contained in the reservoir is kept agitated by the small motor shown. The material flows from the reservoir through the tubing to the striping applicator that is securely mounted in position on the guide roller frame. Film travels from the feed reel through a tensioning device, through the guide rollers under the applicator and onto the drying rack, which holds about 75 ft of film. The rack is equipped with a battery of infrared lamps to facilitate drying. The film is taken up through the powered calender unit and so onto a take-up reel.

Figure 4 shows the applicator head, with the spring-loaded guide rollers, the large roller that positions the film accurately in relation to the applicator orifice and the striping applicator.

Figure 5 shows the orifice and the doctor blade. The orifice width, which controls the track thickness, is usually set at 0.0025 to 0.003 in.

Figure 6 illustrates the power take-up and hot calender unit. It consists of a Graham variable-speed drive, powering a spring-loaded guide roller against which the calender roller is pressed by means of a strong spring-loaded over-center lock, set for about 18 lb. Heat is applied to the calender roller by a heating coil wound on a brass bobbin and mounted as shown to the left of the calender roller. The temperature of the highly polished carbaloy surface of the calender roller is maintained at 270 F ± 20 F.

Great care must be taken during both the manufacture and application of the

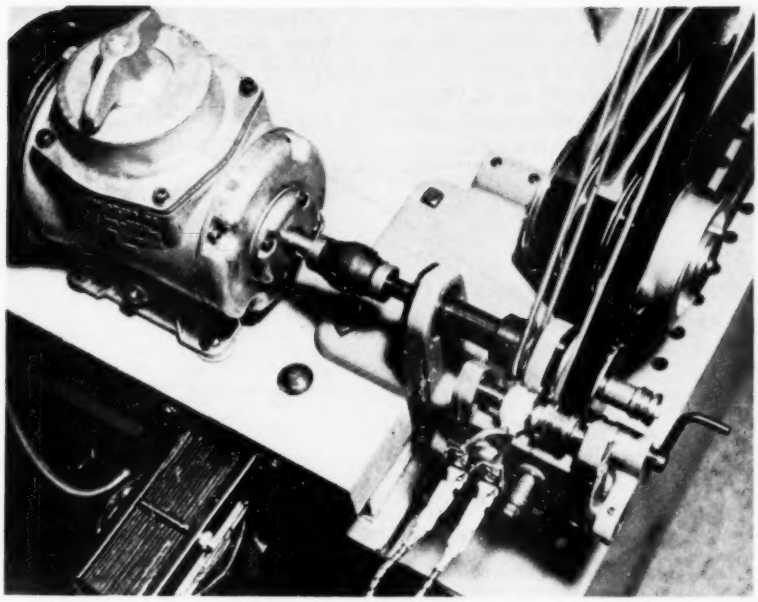

Fig. 6. Power take-up and hot-calender unit.

magnetic composition to avoid the pick-up of dust, lint or other foreign particles. Most track defects have been found to be due to such particles either partially clogging the orifice or becoming caught between the film and the applicator. As a matter of routine, Bell & Howell cleans all film before application of a stripe, both to avoid such difficulties and to assure good adhesion of the track.

Magnetic Properties

Samples of all of the different magnetic pigments used (both black and red) were tested for coercive force (H_c) and remanence (B_r) on a B-H curve tracer.[1]

Performance Testing

All tests are performed on striped film at the standard 16mm sound speed of 7.2 in./sec (24 frames/sec).

Optimum Bias: Using a bias frequency of 50 kc the optimum bias condition is determined based on maximum 1000 cycles/sec output rather than on harmonic distortion considerations. Figure 7, curve A, illustrates a typical output-bias curve for Bell & Howell Soundstripe.

Transfer Characteristic: The input-output relationship is checked at 1000 cycles/sec under conditions of optimum bias to determine the linear range of transfer. A typical transfer characteristic for Bell & Howell coatings is shown in Fig. 7, curve B.

Frequency Response: This characteristic is determined at the optimum bias condition for constant current recording at a level 12 db below the saturation knee as found in the transfer characteristic. The curve of Fig. 7 (curve C) shows a representative frequency-response characteristic for Soundstripe. This curve has been corrected for input circuitry and amplifier-frequency response, and for iron and copper losses in the playback head in order to more nearly show the frequency-response characteristic of the stripe.

Output Uniformity: The output level

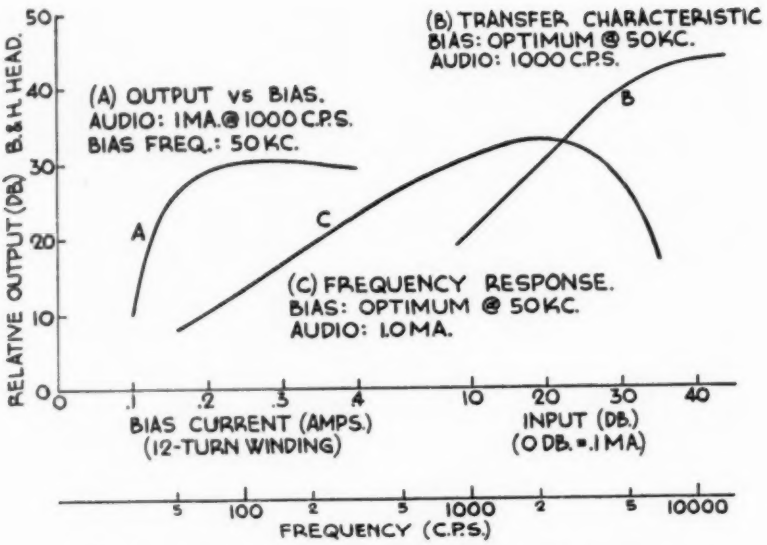

Fig. 7. Performance testing results on Bell & Howell Soundstripe; film speed, 7.2 in./sec.

and uniformity are checked at optimum bias for a record current of 1 kc at a level 12 db below saturation. The graphic representation of output shown in Fig. 8 is a Brush oscillographic recording of a Soundstripe loop recorded under these input conditions.

Harmonic Distortion: This is measured at optimum bias condition with an audio input of 1000 cycles/sec at a level 12 db from saturation.

Test Equipment and Techniques

The drive mechanism now used is a Stancil-Hoffman S5 adapted to mount adjustable 3-head plug-in units. Spring-loaded, felt-covered pressure pads are used to assure intimacy of contact between heads and track.

Bias-Erase Supply: A Hewlett-Packard, Model 200C, oscillator is operated at 50 kc as a source for both bias and erase signals. The output of a laboratory-constructed power amplifier is supplied through a series capacitor selected to resonate with the bias and erase windings at 50 kc. The audio energy coupled to the bias winding in the record head is thus prevented from circulating through the bias and erase metering circuitry.

Audio-Record Supply: Here a General Radio audio oscillator, Type 713-B, drives a laboratory power amplifier. The output is fed through a series metering resistor and a L-C trap tuned to reject the 50-kc bias signal induced in the audio winding of the record head. A Ballantine V.T.V.M. across the series resistor measures the record currents.

Playback Amplifier: The output of a low impedance Bell & Howell head is coupled through an input transformer to a laboratory constructed pre-amplifier and main amplifier patterned after the design of D. L. Clark.[3] This system has a maximum overall voltage gain of approximately 1×10^6 which can be reduced by either 20 db or 40 db by means of decade attenuators and further attenuated with a gain control. Plug-in filter units can be switched in or out as desired. The use of a high-pass filter, cutting off at

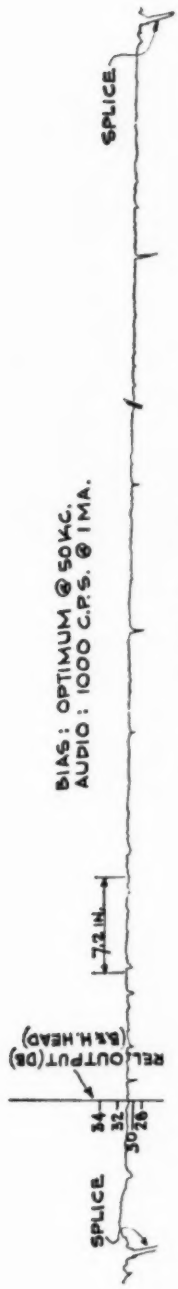

Fig. 8. Uniformity of output.

near 400 cycles/sec, suppresses hum from the power frequency and its harmonics and a low-pass unit cutting off near 7 kc limits the noise spectrum as well as certain undesired signals generated by nonlinearity in the system and recording medium. The use of these filters proves quite valuable in making low-level measurements.

The output of the amplifier is metered with a Ballantine V.T.V.M. and feeds an oscilloscope as well as auxiliary equipment. Harmonic distortion measurements are made by feeding this output to a Hewlett-Packard, Model 300-A, Harmonic Wave Analyzer. Checks on uniformity of output are made on loop-length samples by feeding the playback amplifier output through a rectifier system and into a d-c amplifier and Brush Recorder. Reel-length samples are checked for output uniformity on an Esterline-Angus Recorder where the slower chart movement and greater damping of the pen prove more convenient.

Figure 9 is an overall view of the test station. The racks contain the oscillators and amplifiers with the laboratory-developed drive unit placed in front. A Stancil-Hoffman film transport is shown in the left foreground and the Harmonic Wave Analyzer, oscilloscope and Esterline-Angus oscillograph appear at the right.

Present Status

With current formulations and equipment, Bell & Howell has satisfactorily applied Soundstripe to every type of film received. Adherent, substantially curl-free and dimensionally correct tracks were produced in full and half track, and most recently, in 0.027-in. width for double-perforated film. Investigation of methods of track improvement are, however, continuing.

Present quantitative specifications and typical performance values are as follows:

Fig. 9. Overall view of the test station.

DIMENSIONS

Full track: width and position according to ASA Standards, thickness 0.0004 to 0.0006 in.

Half track: width, 0.049 − 0.003 in.; position of outside track — inner edge of track, 0.057 − 0.002 in. from edge of film; position of inside track — inner edge of track $0.108\ ^{+0.002}_{-0.003}$ in. from edge of film.

Double-perforated: width 0.027 ± 0.002 in.; inner edge $0.029\ ^{+0.002}_{-0.004}$ in. from edge of film.

PERFORMANCE (Full Track)

Coercive force: $H_c = 275 \pm 25$ Oersteds

Residual induction: $B_r = 800 \pm 100$ Gausses.

Output uniformity (Esterline-Angus Recorder):
max. range, ±1.5 db from median;
av. output of reel, ±1.0 db from median; variation within reel, ±1.0 db.

Optimum bias: 0.3 to 0.4 amp at 50 kc.

Harmonic distortion: 0.6% third harmonic.

Noise level: Approx. 60 db below knee of 1000-cycle/sec transfer characteristic.

Acknowledgments

J. P. Weber, of Bell & Howell Co., was responsible for much of the earlier electronic development work in this project.

We wish to express particular appreciation to Kenneth M. Mason, of the Eastman Kodak Co., and H. T. Harding, of E. I. Du Pont de Nemours & Co., for their assistance in supplying samples of films (of both current and superseded types) manufactured by their respective companies.

References

1. "60 cycle hysteresis loop tracer," Armour Research Foundation, Sound Recorder Licensee Service, Bulletin No. 16; July 1946.
2. D. L. Clark, "A flexible decade amplifier," *Audio Eng., 32:* 13, Jan. 1948.

Discussion

George Lewin (Signal Corps Photographic Center): I was wondering whether somebody from Reeves Soundcraft would ask this question. I believe you mentioned that your optimum bias is selected as the one which gives the highest output. Don't you feel then that there's any improvement to be obtained by increasing the bias above that in the interest of getting more uniform steadiness of output?

Malcolm G. Townsley (Bell & Howell): I'd like to answer that. While we evaluate our striping experiments in terms of optimum bias, we set the bias on production projectors considerably beyond optimum, in about the same degree as advocated by Mr. Schmidt.

Mr. Lewin: Just one other question, then. You did say that the oscillograph that you showed here was made on an Esterline-Angus Oscillograph Recorder?

Mr. Kaspin: That's right.

Mr. Lewin: That doesn't show very much high-frequency fluctuation?

Mr. Kaspin: Well, it wouldn't show dropouts. It merely shows a more or less average output.

Editorial Note: In reviewing the discussion transcript, Mr. Kaspin discovered he had misunderstood Mr. Lewin's second question. The oscillographic record shown was actually made on a Brush Recorder (as correctly stated in the paper), rather than on the highly damped Esterline-Angus recorder. The Brush Recorder responds to frequencies up to the order of one hundred cycles, and consequently any dropouts of about 0.01 second or greater duration would be clearly shown.

The correction was forwarded to Mr. Lewin. In reply he indicated his question was prompted by concern over the amount of recorder damping intentionally or unintentionally present during the test runs. Similar test runs made at the Signal Corps Photographic Center on various commercial 16mm magnetic projectors show numerous rapid output fluctuations or "dropouts" up to practically 100%. They do not appear, however, if damping is present in the external rectifier used to feed the Brush Recorder. Experience indicates also that it is very easy to have unintentional damping due to rectifier overload, or by having too much pen pressure.

In subsequent correspondence, Mr. Kaspin submitted the following clarification:

"The output uniformity graph as well as the other data presented in the paper were obtained with the test equipment described and not by the use of any commercial 16mm projector. The aim was to obtain information about the sound track per se with as few extraneous variables as possible.

"Mr. Lewin's comment on the possibility of inadvertently introducing damping into the Brush Recorder setup is, however, well taken. To obtain at least semi-quantitative, experimental data on this question a length of full-track striped film was obtained and gaps were introduced into the track by carefully scraping away the magnetic material. The gap lengths were chosen to produce zero signal intervals of 0.002-, 0.004- and 0.007-second duration when the film traveled at 7.2 inches per second. Recording and playback of a 1000-cycle signal on this film with the regular test setup yielded the following information. The 0.002-, 0.004- and 0.007-second gaps produced apparent dropouts in the Brush Recorder Chart of 1, 2 and 5 db, respectively.

"The statement that, with our setups, dropouts of 0.010-second duration would be clearly shown seems, therefore, to be quite conservative."

Charles O. Probst (formerly U.S. Air Force, Wright Air Development Center; now, Aerophysics Dept., Goodyear Aircraft Corp., Akron, Ohio): When you coat double-perforated stock, do you put a balance coating on the other side?

Mr. Kaspin: As of now we have only coated double-perforated stock experimentally and have not put on a balance stripe. What we will do in the future is as yet undetermined.

Mr. Probst: May I also ask if you have precoated raw Kodachrome, either Commercial or Regular?

Mr. Kaspin: No, we have precoated some raw black-and-white film experimentally, and haven't run into any difficulty in processing, but the processing of Kodachrome involves many more steps than

black-and-white, so we have no information on that.

Mr. Probst: (Added during discussion review) I was trying to bring out the possibilities of recording immediately after processing and editing the projection print. We have done this at Wright Air Development Center, shooting 35mm, reduction-printing on precoated EK-7302 raw stock, editing, recording and showing in about twelve hours. However, from the discussion, it does not appear practical at this time to shoot 16mm precoated reversal film (either color or black-and-white) for immediate recording after processing, though being able to do so would greatly extend the usefulness of this medium as an engineering tool.

R. A. Green (Ft. Belvoir, Va.): When you coat on the emulsion side, can you successfully make prints without getting out-of-focus or slightly fuzzy pictures due to the thickness of the coating?

Mr. Townsley: I think we have had no experience with that yet, Mr. Green. It would depend entirely on the optical characteristics. Theoretically the 0.4–0.6 mil additional thickness could cause some fuzziness, but I don't think any pertinent data exist.

J. E. Aiken (Naval Photographic Center): Do you have any data on the durability of stripes on the emulsion side of the film?

Mr. Kaspin: I have described the testing procedure we used of exposing the film to 140 F for 16 hours then to room temperature and 92% humidity for 8 hours, and going through that cycle eight times, after which we flex the film and try to remove the stripe. Our present coating formulation will pass that test on all the films we stripe, so we presume it's quite durable, but we have no field data.

Magnetic Striping of Photographic Film by the Laminating Process

By ANDREW H. PERSOON

This paper describes a new method of magnetic striping of photographic film using a combination laminating and transfer process. The stripe is transferred from a temporary backing to the photographic film by using heat and pressure to laminate a magnetic tape, face side down, on the film, and removing the backing. The magnetic stripe which remains adhered to the film is very uniform and smooth. This method of striping has the advantages of requiring a minimum amount of space, ease of operation, no solvent hazards, and the uniformity of the stripe can be more easily controlled.

An increased amount of interest is being shown in the magnetic sound track for 16mm motion picture film and there are now available a number of projectors that use both magnetic and optical type sound tracks. The application of magnetic track to the 16mm film, which will be referred to as magnetic striping, has heretofore been done by means of coating a solvent-type magnetic dispersion on the film. This paper describes a new and unique method of magnetic striping whereby the stripe is transferred from a specially constructed tape to the film by a laminating process.

Presented on October 10, 1952, at the Society's Convention at Washington, D.C., by Andrew H. Persoon, Magnetic Recording Tape Div., Minnesota Mining & Mfg. Co., 367 Grove St., St. Paul 1, Minn.
(This paper was received on September 4, 1952.)

This specially constructed tape will be referred to as the laminating tape.

The Laminating Tape

The specially constructed tape, shown in Fig. 1, consists of a two-layer coating on a cellophane backing. The first layer is a 0.0007-in. thick coating of magnetic material which is comprised of a new magnetic oxide dispersed in a resin binder. This new magnetic oxide has an increased amount of remanence flux as compared to the oxides currently being used for magnetic recording tapes, and results in more output. The magnetic layer is applied to the cellophane by the same coating methods used for "Scotch" brand magnetic recording tape and, therefore, the same uniformity may be expected.

The second layer of coating is a 0.0001-in. layer of a thermoplastic type

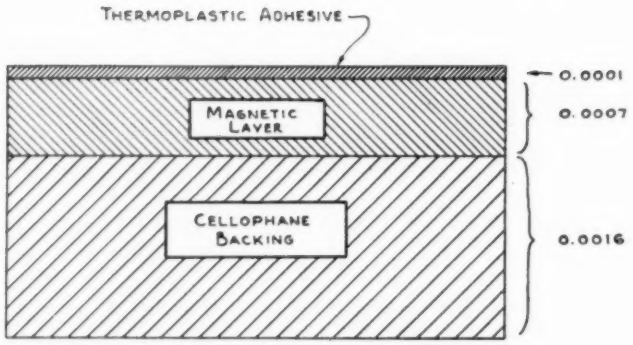

Fig. 1. Cross section through laminating tape.

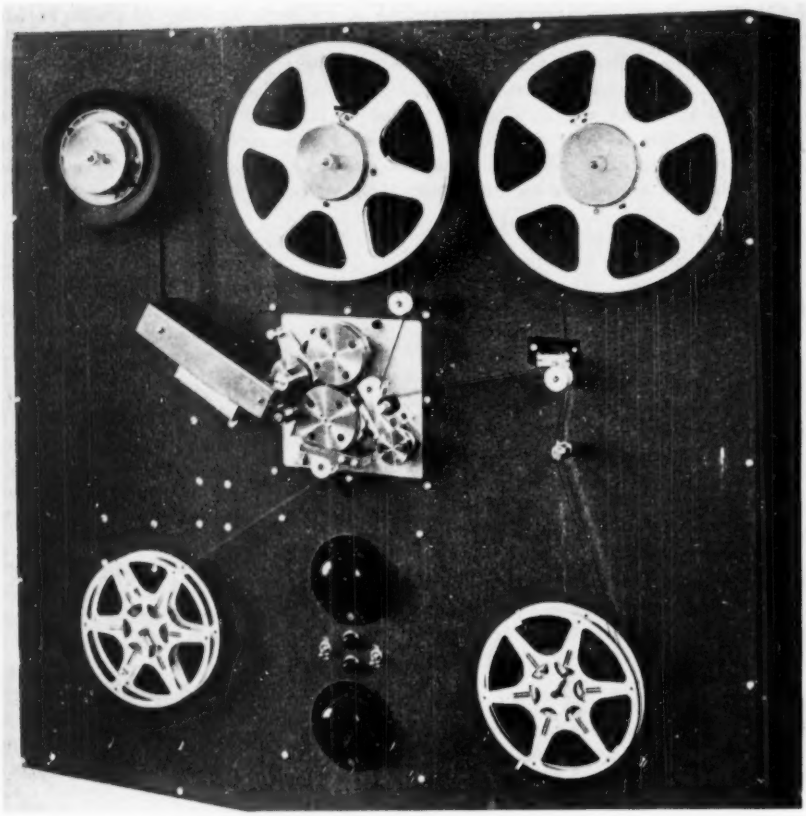

Fig. 2. Laminating machine.

adhesive which can be activated at a temperature of about 225 F. This adhesive forms a good bond between the magnetic stripe and the 16mm film when properly applied by heat and pressure in the laminating process.

The Laminating Process

As was mentioned previously, the magnetic stripe is transferred from the laminating tape to the motion picture film by first laminating the tape to the film and then removing the cellophane backing. This is done with the machine shown in Fig. 2. This machine is a 3 ft × 3 ft × 1 ft box mounted on a table. The striping can be done with this machine in one process operating at a speed of 125 fpm.

Perhaps the best way to describe the process is to follow the tape and film as it goes through the laminating machine. Since the handling of a tape in the narrow widths required for the striping would be very difficult, the tape is supplied in $\frac{1}{4}$-in. widths and slit to the desired width during the striping process. The tape is taken from the supply reel and is passed over a heated platen which is thermostatically controlled at a temperature which will activate the adhesive. When operating at 125 fpm, it is necessary to maintain the temperature of the platen at 440 F. The heated tape is guided onto the motion picture film in such a manner that the two overlap an amount equal to the track width desired. Since both the motion picture film and the laminating tape are accurately slit, this guiding can be done accurately. The overlapped portion of the film and tape then passes through a nip formed by a spring-loaded pressure roller against a steel bed roller. These rollers are located near enough to the heated platen so that the adhesive is still in a plastic state and when the film and tape pass through the nip, they are securely bonded together. The laminated structure then passes onto a rotary slitting knife which trims off the portion of the tape extending beyond the motion picture film. Here, by proper guiding, it is possible to trim the tape so that a straight clean-cut edge is obtained. The portion of the tape which was extending beyond the film is wound up for future use. The structure now consists of a stripe of the desired width secured to the film, but still retains the cellophane film over the magnetic layer. After the adhesive has cooled sufficiently the cellophane is removed by peeling it back through an angle of 180°. This is accomplished by passing the laminated structure under a small idler roller and allowing the cellophane to follow the roller through the 180° angle and then winding it up for disposal. The motion picture film now is complete with a uniform magnetic stripe having a very smooth surface that needs no burnishing. The machine is capable of applying three different track widths: 0.032, 0.057 and 0.100 in. The various track widths are obtained by moving a lever which automatically adjusts the laminating tape guide and the tension on the pressure roller to give a stripe of the desired width.

Performance

The performance of the magnetic stripe made by the laminating process was compared with two samples of commercially available striped film using a Bell & Howell Filmosound 202 projector. The frequency response and relative output of these samples are shown in Fig. 3. The frequency response of the Minnesota Mining sample is flat within 5 db from 100 to 6000 cycles/sec. The relative output was 6 db greater than the best of the other two samples up to 700 cycles/sec and was 3 db greater at the higher frequencies. Due to the fact that the new oxide used in this construction requires a lower bias current, it would be possible to obtain a 6-db gain at the higher frequencies if optimum bias were used.

The uniformity tests on the various

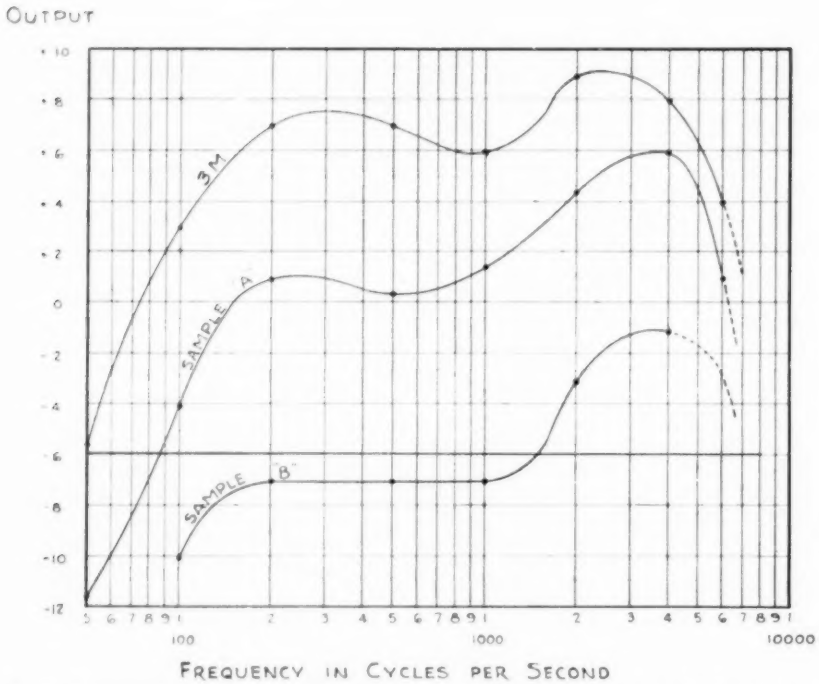

Fig. 3. Frequency response and relative output of magnetic stripe made by laminating process compared with two samples of commercial striped film.

samples were not very meaningful since poor contact with the record-playback head gave a large number of instantaneous dropouts. However, the overall output level varied less than 1 db for the Minnesota Mining sample, while the other samples varied more than 2 db.

The noise level of all three samples was below that of the projector.

Advantages of the Laminated Striping Process

The advantages of the laminated striping process can be separated into two categories: (1) those relating to the process of the stripe; and (2) those relating to the quality of the stripe.

In the first category, we have the following advantages:

1. Simplicity of operation.
2. Small amount of space required.
3. No large heat source needed for drying ovens.
4. No hazards normally associated with solvent coating operations.
5. Very little chance of ruining motion picture film.

In the second category, we have these advantages:

1. Greater output.
2. Magnetic stripe has uniform surface across the width.
3. Uniformity in linear direction is predetermined by coating methods which have been developed over a period of years.
4. Quality control of stripe can be made beforehand on the laminating tape.

Discussion

C. E. Phillimore (Bell & Howell): Do you have any figures on the relative cost of the laminated process as compared with the applied process?

Mr. Persoon: There have been no figures finalized. We feel that we can supply the laminating tape at about a cent a foot.

H. W. Bauman (Ampro Corp.): I was wondering, when you ran those three sets of curves to compare levels, did you change the bias on that particular machine for each one?

Mr. Persoon: No, we did not make any check. We took the projector as it was and put the samples on. We actually spliced the three samples into a large loop and took the checks in that manner. No adjustments were made on the projector.

Mr. Bauman: Well then, which curve had the optimum bias?

Mr. Persoon: We did not check on that. We assumed that the projector was set for one of the other samples which came with the projector.

S. J. Begun (Clevite-Brush Development Co.): First, a simple question—can you give some information on the coercivity and also on the remanence of this new material? My second question might be more difficult to answer. In Fig. 3 you showed three frequency-response curves. They differ in the low-frequency range. Sample B seems to be flat. Sample A, as I recall, shows little hump around 200 cycles, and your own tape shows a considerable hump. Now at this frequency region the signal recorded on all tapes when not equalized should be reproduced with a 6 db per octave rise. If the same equalization is employed for all three tapes they should then all have a flat response. How can the response differences be explained?

W. W. Wetzel (Minnesota Mining & Mfg. Co.): I can answer the first question very simply. The coercivity of the oxide is about 240, the remanence value is about 1000. The second question, I am afraid, Dr. Begun, embarrasses me. I can't explain just why these curves should differ.

M. G. Townsley (Bell & Howell): I think, perhaps, I can help to answer the question. The machine used was a Bell & Howell projector, and in the manner of making those curves, what we have is the overall characteristic from input to output. There is some pre-equalization and some post-equalization in the Bell & Howell design. I think that the noted difference in the tapes, in some way or other, is affected by the pre-equalization and post-equalization characteristics. It is the intent in the projector design to have a slight peak toward the high frequencies in the overall transfer characteristic, and to maintain a reasonably flat curve over the rest of the output. Apparently the different materials respond differently to the compromises which are made in pre-equalization and post-equalization, but those curves being overall transfer curves, should ideally be flat, and not the 6 db per octave fall-off in the low frequencies. This should be compensated for in the projector design.

J. Kenneth Lewis (U.S. Navy, Bureau of Ships): It has been brought out in the paper by Maxwell A. Kerr, at this Convention, that trouble can occur because of the variation in the position of 16mm photographic sound tracks which may be partially covered by a half-track using your process. Mr. Schmidt, in his paper, indicated that operator technique is required to take care of these variations in the position of photographic tracks, and that these variations do exist as practical problems today with the photographic tracks as we find them on regular films which come in for processing. Does your process have any means in it whereby operator techniques can be used to take care of this irregularity in optical sound-track position, especially if it occurs abruptly at splices?

Mr. Persoon: The guiding of the tape can very easily be adjusted to set the magnetic track at any particular spot wanted on the film, since it's merely a matter of moving the tape guide to the proper position. Does that answer your question?

Mr. Lewis: To continue the question a little more—apparently in the case of some of the coating techniques now used it is necessary to stop the process momentarily, reset the coating device, and then proceed, with the magnetic coating at a slightly different adjustment at such discontinuities as splices; I gathered this from Mr. Schmidt's paper. I am wondering if your process lends itself to this procedure?

Mr. Persoon: Yes, it would. There is no reason why it could not be done.

James F. Cornell (General Electric Co.): Perhaps you covered this in the paper and I missed it, but is this process applicable to raw stock without damage to the photographic emulsion due to the heat that's transferred?

Mr. Persoon: Yes, the machine is so designed that the motion picture film is kept at the ambient temperature, and the only rise in temperature you would expect in the motion picture film would be due to the adhesive coming in contact with it. At the time the adhesive comes in contact with the motion picture film its temperature is only 200 F, so I'm sure there would be no damage.

Harold C. Barr (Sandia Corp.): I wonder what happens to this stripe when it is applied across the typical splice where the film is overlapped. There might be some air trapped underneath. Will it continue to adhere in use?

Mr. Persoon: The portion where obviously there would be a little air trapped is the so-called "square" part of the butt-end splice; however, this loosens only a few thousandths of an inch, and beyond that the lamination will again adhere.

Mr. Barr: Does it adhere equally well either to the emulsion side or to the base side?

Mr. Persoon: Our experience in that has been rather limited. However, on black-and-white we have had no difficulty with adherance to the emulsion side.

Leonard A. Herzig (Prestoseal Mfg. Corp.): I understood you to say that there would be loss in sound with the overlap splice. Wouldn't this be eliminated with a butt-weld splice?

Mr. Persoon: Yes, it definitely would.

Ernest W. Franck (Reeves Soundcraft Corp.): I'd like to ask a question referring to the chart showing the difference in output of the new oxide compared to others. There was no indication of distortion levels on it, and without that information the chart does not seem complete. Do you have the information? Were the runs at different distortion levels?

Mr. Persoon: No, they were not. We tried to keep all runs below one percent third harmonic distortion.

Mr. Franck: But there was no adjustment made for bias?

Mr. Persoon: No.

Mr. Franck: But at different bias adjustments, the differences might be less?

Mr. Persoon: Yes, I think that could be.

R. A. Green (Ft. Belvoir, Va.): You mentioned that you coat raw film stock. What happens during processing? Are there any characteristic changes in the coating such as blistering, separation or shrinkage?

Mr. Persoon: I am sorry, but there has been a misunderstanding. We have not actually coated raw stock, and therefore I cannot answer your question from experience. I did make the statement, however, that if raw stock were to be used, I do not think the laminating heat would affect the emulsion.

Mr. Lewis: In the event you should be required by virtue of the photographic track position to half-stripe on the picture side of the track, does your process lend itself to doing so?

Mr. Persoon: At present we cannot half-track on the picture side since we use a tape wider than the desired magnetic track width and slit off the excess. For half-tracks, we are limited to the space from the photographic track centerline out to the film edge.

Magnetic Sound Tracks for Processed 16mm Motion Picture Film

By THOMAS R. DEDELL

The procedure developed at Eastman Kodak Co. for applying magnetic sound tracks to processed 16mm motion picture film is fully described. Complete details are given for the coating composition, the dispersing technique and the method of coating. The bead coating method is used. Problems related to coating on film are discussed. Sound-quality measurements are reported comparing these coatings with commercial quarter-inch tape.

IT IS THE PURPOSE of this paper to describe in detail the procedure developed in the laboratories of the Eastman Kodak Co. for applying magnetic sound tracks to 16mm motion picture film. For this purpose, the track width is limited to one-tenth of an inch or less, and the track is applied only to processed Eastman film.

Coating Formula

The formulas described here are composed of an iron oxide, as the basic ingredient, dispersed in a mixture composed of a binding material, solvents, and a plasticizer in appropriate quantities.[1] The selection of the materials and their amounts are determined by the following conditions:

1. The magnetic material must have physical and magnetic characteristics capable of rendering desired sound quality.

2. The binder-solvent combination should allow easy dispersion of the oxide in order to obtain acceptable sound quality.

3. The coating must give satisfactory adhesion to both the base and emulsion of film.

4. The binder, in addition to giving good adhesion of the coating to the film, must also provide adequate binding of particles within the coating.

5. The coating should cause no unacceptable physical deformation of the film.

6. For use with the bead coating method, the solvents must be high boiling so that negligible viscosity changes occur while coating. At the same time, it must be practical to cure out the solvents at temperatures not above 110 F.

7. The solvents must be good solvents for the binding material and prac-

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Table I. Magnetic Coating Composition

200 parts*	red iron oxide IRN-110
40 parts	40–60 SS type cellulose nitrate
17 parts	butyl alcohol
120 parts	cellosolve
906 parts	amyl acetate (commercial grade)
136 parts	butyl cellosolve
8 parts	AA grade castor oil

* Parts by weight.

tically nonsolvents for the base materials.

8. The amounts of the various ingredients of the formula must be adjusted so that a coating of proper width, thickness and oxide content is obtained.

The type of formula which we have found best to meet these requirements is based upon the use of a red iron oxide dispersed in cellulose nitrate as the binding material. The complete composition* is given in Table I.

The iron oxide is manufactured by the C. K. Williams Co. The castor oil is Baker's grade AA. The binder, 40–60 SS type cellulose nitrate, is obtained from the Hercules Powder Co. It is delivered wet with butyl alcohol (70% nitrate, 30% alcohol). The butyl alcohol indicated in the formula is the amount that is introduced with the nitrate.

Dispersing Method

The sound quality of magnetic sound tracks is greatly influenced by the degree of dispersion of the iron oxide particles. Particle flocculation causes increased noise levels and lower signal-to-noise ratios. Consequently, the magnetic-coating composition must be subjected to a dispersing treatment in order to obtain adequate separation of the iron oxide particles. Of the many dispersing methods tried, ball milling has been most effective. Porcelain mills with flint balls have been used.

Our procedure for preparing a dispersion is as follows: The cellulose nitrate binder is stocked in solution form using part of the solvent of the dispersion formula. The stock solution which is used by Eastman Kodak Co. is given in Table II.

Table II. Stock Solution for Cellulose Nitrate Binder

40–60 SS type cellulose nitrate	10%
Butyl alcohol	4.3%
Cellosolve	30%
Amyl acetate (commercial)	55.7%

Many other stock solutions are possible using different amounts of solvents. The various constituents of the coating composition are put into a ball mill. The order of addition of ingredients is of no importance. The ball mill is then rotated until a satisfactory dispersion is obtained. The milling time depends, among other things, on the viscosity of the mixtures and the size of the mill. For making tracks of 0.100-in. width, one-gallon mills at 60 rpm and 75 F give good dispersions in 24 hr. Milling up to 150 hr shows no significant change in sound quality. Very long milling gives poorer sound quality. With quart mills, the same dispersion at the same rpm requires a minimum of 60 hr of milling.

The coating composition for 0.100-in. width tracks has a shelf life of at least thirty days. In that time, there is no appreciable change in sound quality of the coated tracks. Tests are not completed for holding times beyond thirty days. Because of oxide particles settling out, all dispersions should be tumbled for at least 30 min before coating. Narrower tracks are made from dispersions of higher viscosity. The higher viscosity dispersions have longer shelf lives. Work is now in progress to improve the dispersions and the keeping properties of the dispersions.

Coating Methods

The method used for applying the magnetic dispersion to film must provide

* The Eastman Kodak Company does not intend to sell the coating composition.

Fig. 1. The coating machine; see text for description of keyed parts.

a coating of proper physical characteristics, including the following:

1. The width and thickness of the track should be uniform. Tracks 0.100 in. wide on film have been made to conform with the proposed American Standard PH22.87.

2. The surface should be flat to provide intimate and uniform contact with the magnetic recording and playing heads.

3. The surface should produce a minimum of wear on the magnetic heads.

In this investigation, several possible means of applying the coating were considered. One of these was an extrusion method. In this case, the fluid is metered to the film from a small tube. The method has the possible advantage of using a closed system and of applying a coating thickness which is independent of the viscosity of the dispersion. Experimentation has indicated that this technique is not entirely satisfactory for the purpose. The main difficulties are metering problems and width control of the track.

Another possibility is to apply the dispersion by an intaglio printing process. In this case, the fluid dispersion is ap-

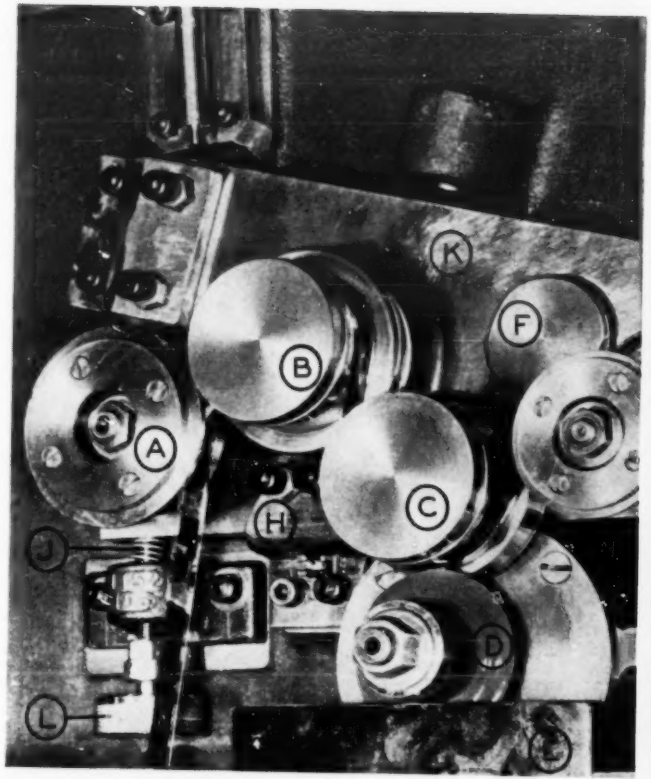

Fig. 2. Close-up of coating mechanism; see text for description of keyed parts.

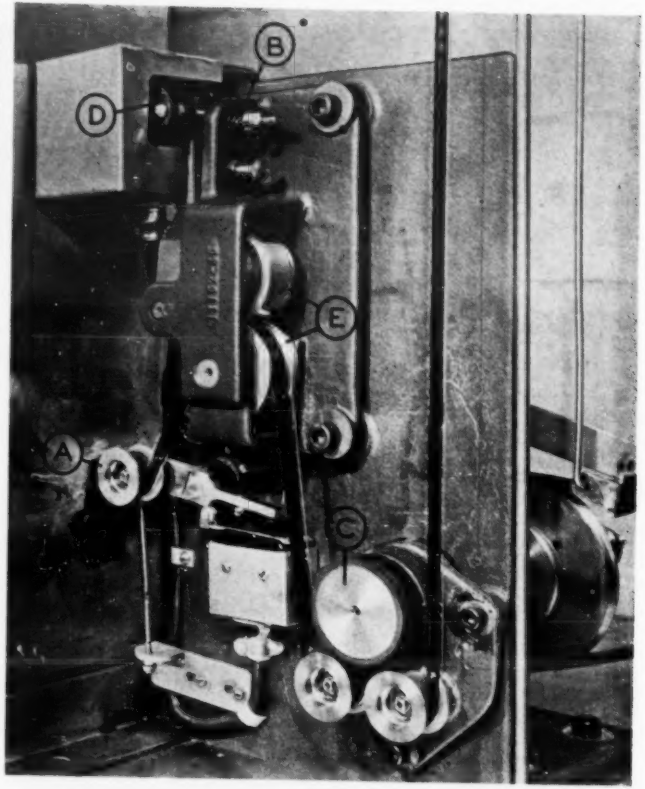

Fig. 3. Pressing device; see text for description of keyed parts.

plied into recessed grooves of a coating wheel and subsequently transferred to the film. Experiments with this method have shown that satisfactory transfer of the dispersion from the intaglio grooves to the film is difficult to obtain.

A more successful process has proved to be a bead coating method. In this case, an applicator wheel rotates in a tray of dispersion and transfers the magnetic composition by means of a liquid bead to the film, which passes above the applicator wheel. This is a well-established coating method and is used for film lacquering.[2] Consequently, most mechanical problems connected with obtaining satisfactory coating uniformity have already been solved. One disadvantage is that surface tension causes the dry surface to be slightly convex. Flatter surfaces can be obtained by pressing the coatings. Also, this method is limited to coatings under 0.20 in. in width. Wider magnetic tracks cannot be made sufficiently uniform in thickness when coated by the bead method. The cause for this is the high viscosity needed to obtain proper oxide concentration in the track. Low-viscosity bead applications can be very uniform. The bead method, to be successful, requires rigid control of the viscosity of the dispersion, the rotation speed of the applicator wheel, the speed of the film, and the separation between the applicator wheel and the film.

Bead Coating Method

Referring to Fig 1, the coating machine consists of a supply reel (A), a bead coating mechanism (B), a drying cabinet (C), a pressing device (D), and a take-up reel (E). The film is transported and kept at proper tensions by three friction-driven rolls. A rubber-covered drive roll (F) is located before the coating is applied. Another drive roll is in the drying cabinet. A third drive roll (H) is after the pressing device. The motor beneath the table is connected by silent chains to the drive rolls. At present, the coatings are made at 20 fpm. At this speed, the curing time has been 2.8 min. The air temperature in the curing cabinet should not exceed 110 F, otherwise film brittleness problems may result. Higher coating speeds are undoubtedly possible. The maximum practical speed has not yet been determined.

Figure 2 is a close-up of the coating mechanism. Referring to this picture, the entering film first contacts a positioning roll (A), which, by means of an outside flange, forces the film toward an inner flange on a positioning roll (B). In this manner, film is made to leave roll B always from the same position. As a result, the film is fed to idler (C) so that the inner edge which is to be coated is in a constant position. Below the idler is an applicator wheel (D) which dips into tray (E) and brings up liquid dispersion. The film on the idler can be raised or lowered by the adjusting knob (L). A dial gauge records the positioning of the film. In raising or lowering the film, the plate (K) on which the idler and positioning rolls are attached pivots about point (F). The applicator roll rotates so that the top of the roll moves in the same direction as the film. A setscrew (H) prevents the idler roll from contacting the applicator roll. A spring (J) balances the mounting plate (K) so that if an excessively thick splice should pass between the applicator roll and the idler roll, no large forces would be acting on the bearings. The coating formulas are adjusted so that a normal splice can pass through without having the applicator roll touch the film.

Figure 3 shows the pressing device. This device is used because it produces flatter surfaces on the coatings, providing better contact with pickup heads and less wear of pickup heads. Referring to Fig. 3, the film leaving the drying cabinet passes under idler (A) which is on a pivot. The film passes between two rollers (E) (neither is

Table III. Relation of Track Width to Viscosity of Coating Composition

Track width	Amyl acetate	Brookfield viscosity	Width of applicator wheel	Film speed
0.100 in.	906	11	0.061 in.	20 fpm
0.050 in.	906	11	0.032 in.	20 fpm
0.032 in.	515	76	0.029 in.	20 fpm

driven) which are under tension by means of spring (B). Splices will not pass through these rolls except by using prohibitive tensions from the drive roll (C). When a splice hits the pressing rolls, the film momentarily stops allowing idler (A) to drop, thereby actuating a micro switch which energizes a solenoid (D) which opens the pressing rolls and allows the splice to pass. The film tension then returns to normal and pressing continues. The rolls are 2 in. in diameter. The spring tension is adjusted so that an unpressed coating 0.55-mil thick is pressed to a 0.40- to 0.45-mil thickness.

In applying coatings by use of this equipment, it is necessary to adjust the viscosity of the coating composition to the width of track to be applied. The formula, as given in Table I, is for tracks having a width of 0.100 in. For narrower tracks, it is necessary to use a higher viscosity coating composition. Viscosity adjustments are made by varying the amyl acetate content. The formula, with appropriate viscosity adjustments, can give acceptable sound tracks for 16mm film perforated along one edge, using either 0.100-in. or 0.050-in. tracks, and film perforated along both edges on which a 0.032-in. track is coated outside the perforations. Specific data are listed in Table III for making tracks 0.100, 0.050 or 0.032 in. wide. In each case, the applicator wheel was 2 in. in diameter and was rotated at 28 rpm. The formulas used for different width tracks vary only in amyl acetate content. Viscosity readings are on a Brookfield viscometer using a #2 spindle at 6 rpm at 80 F. The Brookfield viscometer has been used because of the ease of measuring viscosity. For experimental work, it is very helpful to know the viscosity of all dispersions. For production work, it has been found that a given formula can be reproduced so well that viscosity measurements are unnecessary. Before using a dispersion, check coatings are made to insure proper width and thickness of the coating.

Coating Problems

It is necessary that the coating solution lend itself to application to either the base side or the emulsion side of the film. In the case of Eastman films, two types of base are in current use.[3,4] At the present time, Cine Kodak 16mm and 8mm Kodachrome films and Cine Kodak black-and-white films for reversal processing are on a cellulose acetate-propionate base. Kodak Blue Base Reversal film and positive print films are on tri-acetyl cellulose acetate base.

Adhesion to the emulsion is primarily determined by the type of binder used. Small amounts of water in the formula tend to increase adhesion to the emulsion but reduce adhesion to the film base. Most binding agents give poor adhesion to emulsion regardless of the solvents used. Magnetic sound tracks coated from the proposed coating composition have satisfactory adhesion to the emulsion.

On the base side of film, much of the adhesion results from solvent attack. For a given magnetic oxide formula, the high-acetyl acetate base will be attacked less than the cellulose acetate-propionate

Table IV. Sound Recording Properties

Sample	Saturation output	2% dist. output	Zero signal S/N	2% dist. S/N	Freq. of 10-db loss	Amplitude modulation
Commercial tape	24.7 db	16.4 db	66.7 db	57.7 db	7300 cps	1.5%
Experimental coating	21.3 db	10.8 db	67.8 db	52.3 db	7200 cps	6.0%

base. The magnetic oxide coating composition proposed in this paper has been found to be satisfactory for both of these film base materials.

Curl of the Film Due to the Coating

The film curl due to the coating is closely associated with adhesion. Each is controlled by the amount of solvent attack on the surface. An increase in solvent attack improves adhesion and tends to increase curl. Thus, the formula must be adjusted so that the solvent attack gives the necessary adhesion of the track without causing undesirable curl of the film. The formula proposed here gives no curl problem for high-acetyl or acetate-propionate bases, provided the coating is cured by circulating air at 110 F for at least 2.8 min.

However, unacceptable curl does result when tracks 0.100 in. wide are coated on cellulose acetate-butyrate base. Although this base is not being used for any current Eastman 16mm films, some 16mm film perforated along one edge has been produced in the past on this base. Tracks 0.050 in. wide or less do not cause objectionable curl when coated on films using this base.

Surface Irregularities

Surface tension causes the wet coating to form a convex surface. If the solvent has high attack for the surface to which the coating is made, it is characteristic for the coating to dry with a crack in the middle. In general, flatter crack-free surfaces are obtained if the solvents have low attack for the surface and if the formula contains a small amount of very high-boiling solvent such as butyl cellosolve or butyl lactate. Usually, formulas having very low attack on film base will give coatings having irregular edges, which must be avoided.

Sound Quality

The sound quality of magnetic tracks 0.100-in. wide and 0.4-mil thick has been determined by coating tracks on 16mm film which was later slit to $\frac{1}{4}$-in. width. The track was positioned in the middle of the $\frac{1}{4}$-in. strip. Sound measurements and comparisons with commercial magnetic tapes were made in the Kodak Research Laboratories on a high-quality $\frac{1}{4}$-in. tape recorder.

There are two basic difficulties in comparing 0.100-in. magnetic tracks with commercial $\frac{1}{4}$-in. tape. A narrow track will never have width and surface uniformity that is possible with $\frac{1}{4}$-in. tape. Since the magnetic heads used in testing tapes were 0.125-in. wide, this means that all edge variation on narrow tracks was picked up by the heads. Also, the narrow tracks were tested on base material 5.5-mil thick. Commercial tape base is about 1.5-mil thick. This thickness difference and the associated difference in flexibility greatly affects head contact with the tracks. Both of these factors act to the detriment of the narrow track.

Table IV lists various sound measurements for a track 0.100-in. wide and 0.4-mil thick, and also lists comparison figures typical of the best commercial tapes.

All data reported here were determined using a nominal bias current,

which is defined as that value of bias current which gives a maximum output level for a constant input level at 300 cycles/sec. The tape speed was 7.5 in./sec.

Other terms used in the table are defined as follows:

1. Saturation output is the maximum output level obtainable from the tape, irrespective of distortion, at nominal bias and at the audio frequency which gives maximum undistorted output.

2. Two per cent distortion output is the equalized output level which gives 2% distortion at a 480-cycle signal recorded at nominal bias.

3. Zero signal-to-noise ratio is the ratio of saturation output to zero signal-noise level. Zero signal-noise level is the tape noise measured after the tape has been subjected to a record head field of nominal bias but zero audio signal.

4. Two per cent distortion signal-to-noise ratio is the ratio of an audio signal of output level which results in a 2% distortion to the 2% noise level. The frequency of the signal is that which gives maximum output level at nominal bias. Two per cent noise level is the noise level when the magnetization of the tape is equivalent to that induced by a signal of such amplitude as to result in a distortion level of 2%.

5. Amplitude modulation is an undesired fluctuation in the reproduced level of a signal which was originally applied to the recorder as a signal of constant level. The amount of the fluctuation is expressed as a percentage of the average signal level.

In general, the 0.100-in. tracks compare favorably with $\frac{1}{4}$-in. tracks. The Eastman coating is about 0.100-in. wide compared with the 0.125-in. widths measured on the commercial tapes. This width difference accounts for about 2 db in output levels. For projector use, outputs and signal-to-noise ratios for 0.100-in. tracks are adequate. The amplitude modulation is considerably higher than for $\frac{1}{4}$-in. tapes. Amplitude modulation for original photographic tracks is usually under 1%. 16mm prints often have amplitude modulation near 5%. At present, future improvements in amplitude modulation are more necessary than increased outputs or signal-to-noise ratios. However, if 0.032-in. tracks are ever used, increased outputs may be very desirable.

The publication of this paper does not constitute any recommendation on the part of the author or the Eastman Kodak Co. for the manufacture, use or sale of any substance, chemical, film, apparatus or method covered by any patents now in force or which may issue in the future. While investigation indicates that there are no patents dominating the apparatus and method hereby described, publication of this information is not any assurance, warranty or indemnification on the part of the Eastman Kodak Co. or the author with respect to the infringement of any patents now in force or which may issue in the future.

Acknowledgment

All sound tests of magnetic tracks were made in the Kodak Research Laboratories by W. K. Grimwood and J. R. Horak under the direction of Dr. Otto Sandvik. The author also acknowledges the assistance of D. I. Mayne, Jr. and H. J. Krall in developing the coating formula and coating technique; and H. F. Betz, R. L. White, H. L. Fitch and R. L. Wells who aided in the development of this program for commercial use.

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Discussion

S. J. Begun (Clevite-Brush Development Co.): Before I ask my question, I would like to express to Mr. Dedell my appreciation for a very excellent presentation on this particular subject matter. Now, to my question. You mentioned, I believe, that you could store dispersions for approximately 30 days. I wonder whether any particular conditions during storage have to be maintained as far as temperature is concerned, and whether any other precautions have to be observed?

Mr. Dedell: We ordinarily store the dispersion in 8-oz bottles. We usually make up dispersion in gallon mills and pour it from the gallon mill into 8-oz bottles; you get something like five 8-oz bottles of dispersion. These are kept tight and are set on a shelf for as long as 30 days, and we use them up to that length of time. Just before we use them we tumble them for about 30 minutes. Outside of that there are no special conditions for keeping. They do not have to be agitated the whole 30 days, or anything like that.

Mr. Begun: Might I ask another question then? I am wondering whether you feel that this method of applying a magnetic striping to film could be brought to a point where the individual processor, or maybe the smaller camera shop, might be able to apply it?

Mr. Dedell: I think the answer to that is the cost of the machine. The coating mechanism is a precision instrument. You have to have the idler roll and the applicator roll within about a ten-thousandth of an inch of being a perfect circle, and that adds quite a bit to the cost of the machine and the maintaining of it. Anyone can make the coatings if they can afford the machine, and anyone here with about 10 minutes' instruction could make coatings on it.

E.W. D'Arcy (De Vry Corp.): What factor of control do you have over the recording characteristics of your striping?

Mr. Dedell: Only in following the directions which I have just given for making up the dispersion formula. That is, you have to weigh out the quantities accurately, the viscosity must be controlled correctly, and distance between the applicator roll and the film must be accurately set. With proper attention to these points, you will then end up with tracks of uniform quality.

George Lewin (Signal Corps Photographic Center): I might have missed this point in your presentation, but did you indicate whether or not this coating can be applied on the inside half of the track, or does it have to be on the outer edge of the film?

Mr. Dedell: I didn't mention that. The coating can be made in widths up to 100 mils, any width you like, and it can be positioned any place you want to put it.

Mr. Lewin: Also, you gave some figures on percentage of amplitude modulation. Could you tell us a little bit more as to how you measure it? What I'm getting at particularly is what rates of amplitude variations are included in your figures? The percentage figures seem rather low.

J. R. Horak (Kodak Research Laboratories): These amplitude modulation figures were taken at 3000 cycles at $7\frac{1}{2}$ in. per second, and they are average readings. They are not peak readings at all; they're average fluctuations.

Mr. Lewin: In other words, they don't show very rapid fluctuations, do they?

Mr. Horak: No, only up to 500 cycles.

Mr. Lewin: They do show up to 500 cycles, however, do they not?

Mr. Horak: Yes, we have a 500-cycle low-pass filter following the detector.

Mr. Lewin: That just doesn't seem to jibe with graphs that I've seen.

Mr. Horak: Well, we have a rather high pressure on the pressure roller holding the tape to the record head and that may account for the difference.

Mr. Lewin: Were these figures taken on the new Eastman projector?

Mr. Horak: No, this is a special machine we have built in our own laboratory just for making tests on $\frac{1}{4}$-in. tape. It has very high pressure on the record head and also pretty high tension on the loop drive.

Mr. Lewin: In other words, it doesn't represent what you'd realize on commercial projectors.

Mr. Horak: We are trying to find out exactly what the tape is capable of. There-

fore we try to get the tape in intimate contact with the heads to see just what is a factor in the tape itself exclusive of the tape drive.

Mr. Lewin: That is particularly interesting then, because I think this is the first time we have any actual proof that possibly the tape itself is very uniform, and that a lot of our present troubles originate in our reproducers.

Mr. Horak: Some of the commercial tape is very good that way, particularly the ¼-in. tape on thin base stock. Our own material averages 6%, with perhaps instantaneous peaks up to 10 or 20%.

Mr. Lewin: It certainly does point up the fact that most of the trouble we're having is due to poor contact in the commercial-type reproducers.

Mr. Horak: Yes. Also I'm very careful at all times, whenever I make a new test on a narrower or wider track or on a different type of tape, to lap the heads for each tape.

B. L. Kaspin (Bell & Howell): In your coating mechanism, do you have any sort of control device to keep the magnetic material in the reservoir into which the beading wheel dips at a constant level?

Mr. Dedell: No, it is filled by hand.

Mr. Kaspin: The thickness of the coating doesn't vary, then, as the material in the reservoir goes down?

Mr. Dedell: Not for a difference of a half an inch in level.

Charles O. Probst (Goodyear Aircraft Corp., Akron, Ohio): Did I understand you to emphasize that you had only worked with processed stock?

Mr. Dedell: That's right.

Mr. Probst: Do you have reason to believe that you will be in any trouble with Kodachrome, coating it before exposure or processing?

Mr. Dedell: Yes; you cannot coat, with this formula anyway, on either the base side or the emulsion side of raw-stock Kodachrome. The track will come off in the processing.

Donald Bleier (Signal Corps Engineering Laboratories): With respect to the drying portion of the machine, could you give a little more detail as to whether or not you use lamps, or just air, and how long is the film exposed to the drier?

Mr. Dedell: I mentioned that the film is dried for 2.8 minutes when we're running at 20 feet per minute. The drying air blows through cross-strip heaters.

R. Paul Ireland (EDL Company): How closely are you able to control the width of the coating? Having the coating roller only about two-thirds the width of the expected track, one might expect some difficulty in controlling the track width.

Mr. Dedell: Measurements we have made on the track along its length show that we usually control the width within plus or minus 1 mil. The specifications call for plus or minus 2 mils.

Notes on Wear of Magnetic Heads

By G. A. DEL VALLE and L. W. FERBER

Since physical pressure (under contact) is essential between a magnetic head and magnetic media to provide high-quality sound, it is of extreme importance to determine the operating life of the head. This paper describes the methods used and the results obtained in establishing the wearability of the record-reproduce heads on RCA magnetic projectors.

USING PRESENT-DAY striped film and the standard sound film speed of 36 fpm, there were three things which could be varied in designing a magnetic recording head for a maximum life expectancy. These were: (1) the magnetic material for pole pieces of the head; (2) the force holding the head against the sound track; and (3) the shape and surface condition of the head.

The magnetic materials universally used for magnetic recording heads are in the high nickel-iron alloy group, one of which is used in the record-reproduce heads on RCA magnetic projectors. These materials are soft physically and cannot be hardened by heat-treating; and the electroplating of hard or wear-resistant materials on these alloys affects the important magnetic properties for which they were chosen. When used as a record head the pole pieces must have the following characteristics: the hysteresis and eddy-current losses must be reasonably low, because of the high-frequency bias voltage; the magnetic retentivity must be low in order to avoid a noisy system resulting from the application of a unidirectional magnetic bias to the film; and the saturation value must be high enough so that the magnetic coating on the film will saturate first. When used as a reproduce head the pole pieces must exhibit a low retentive force to assure that little noise will be introduced into the system, and in addition the permeability for low-flux densities must be high in order to obtain efficient operation at the low values of flux obtained from the film.

Experience has shown that a prerequisite for a high-quality recording system is to have the magnetic heads (especially the reproduce head) in intimate contact with the magnetic coating. Because of irregularities on the surface of the magnetic coating on the film, and the friction in the pivots of the arm which holds the head, it is necessary to apply a force to the head assembly sufficiently great so that even under the most adverse conditions the head will contact

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the magnetic coating. Insufficient force has its worst effect on the reproduction of high-frequency signals in the form of low and erratic output voltages. Excessive force will distort the unsupported edge of the film carrying the magnetic track to such an extent that the complete width of the head will not contact the track, and low output voltages will result. If excessive force is allowed to remain on the head and the position of the head is not changed, the head will finally wear to fit the curve of the film and produce the proper output voltages. But such a situation will decrease the life of the head many times. The proper force is one which is the minimum to overcome the pivot friction, and which will yet produce the proper output voltages over the required frequency range with a minimum of amplitude modulation and maximum head life.

The best contour for the head is the maximum radius allowable that will be less than the radius of the sound drum and will also permit lateral adjustments to bring the gap of the head in contact with the film. This provides the maximum film support by the pole pieces as the head wears and also insures maximum head life. There is a direct relationship between the radius of the contour of the head and the smoothness of the low-frequency response of the head. The larger the radius, the lower the frequency of the bump in the frequency response due to the geometry of the head and the recorded wavelength. Since this bump is relatively high in magnitude and covers about half an octave in the response, it is difficult to compensate for in reproducing. Therefore, the most direct and effective way to produce a smooth low-frequency response is to design the head so that the bump will be below the lowest frequency required.

The surface condition of the head is important to both the wear and the electrical performance. The finer the finish on the pole pieces, the less wear will result during the first portion of the head life. Of course, the cost of finishing a head for the least possible wear would be prohibitive, and a compromise has to be reached. The compromise finish must be one which will produce a well-defined nonmagnetic gap, so that the head will perform as soon as it is assembled into the complete projector, and not waste production time by "wearing in" the head.

The two items which contribute to wear on magnetic heads, the effects of which cannot be minimized by head design, are the surface condition of the magnetic coating and the film speed. All the present-day magnetic tracks on films are very abrasive as compared to magnetic tapes. If magnetic tracks with a surface equal to that of present-day tapes could be used, other factors remaining the same, it is reasonable to assume that heads would last at least four times longer. There is one great factor in favor of the tape as a magnetic medium as compared with a track on film and that is the flexibility of its base stock. In tape machines the tape conforms to the shape of the head whereas in a projector the head has to be forced against the stiff film to get the contact required. This abrasive condition of magnetic tracks on film is a problem the film vendors and service agencies must remedy.

Slower film speeds would undoubtedly increase head life but the frequency range would be decreased and poor picture quality would result.

The actual testing procedure used in evaluating these heads is straightforward. A standard projector from the production line was used, with the amplifier separated from the rest of the projector so as to eliminate any chance of the hum pickup affecting the readings. Loops of brand new film, 10 ft in length, were used to simulate extreme operating conditions. All the film used was exposed and processed, so that it was stiffer than clear test film. A new loop was

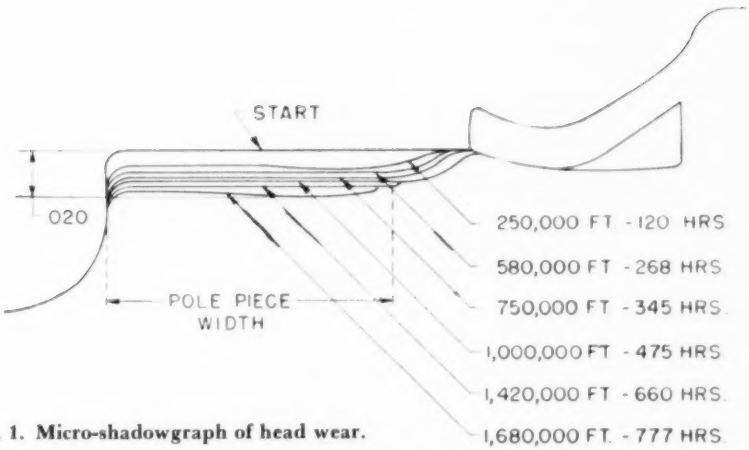

Fig. 1. Micro-shadowgraph of head wear.

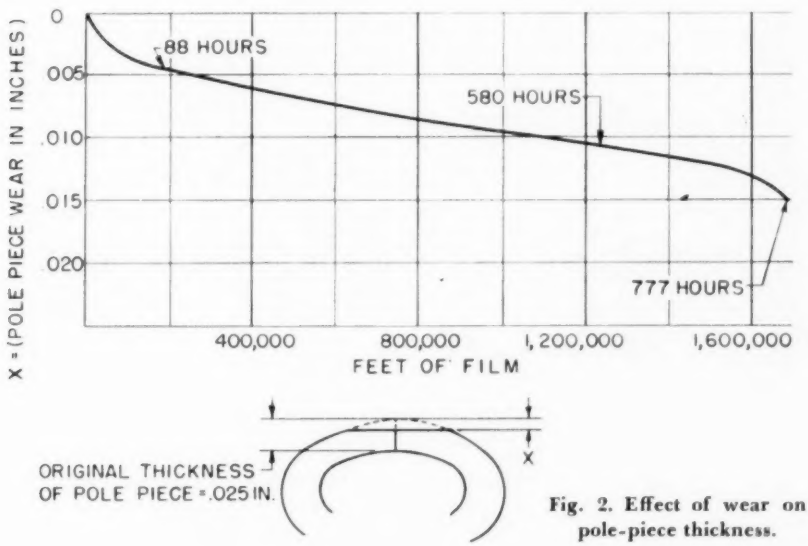

Fig. 2. Effect of wear on pole-piece thickness.

used every four hours, and the contour of the head was checked on a Jones & Lamson comparator at 100:1 magnification, every eight hours (Fig. 1). These loops had 6000 cycles/sec prerecorded on them to check the output voltage of the head throughout the tests.

In the 4-hr period, one loop passed 2160 times through the projector and there was no noticeable drop in the output voltage of the 6000-cycle signal. The heads tested were used to record and reproduce signals after the tests were terminated and they still functioned satisfactorily.

Figure 2 shows the rapid wear of heads during the first 88 hr in test. This is due to the small pole-piece area of a new head supporting the film and to its surface condition. The remainder of

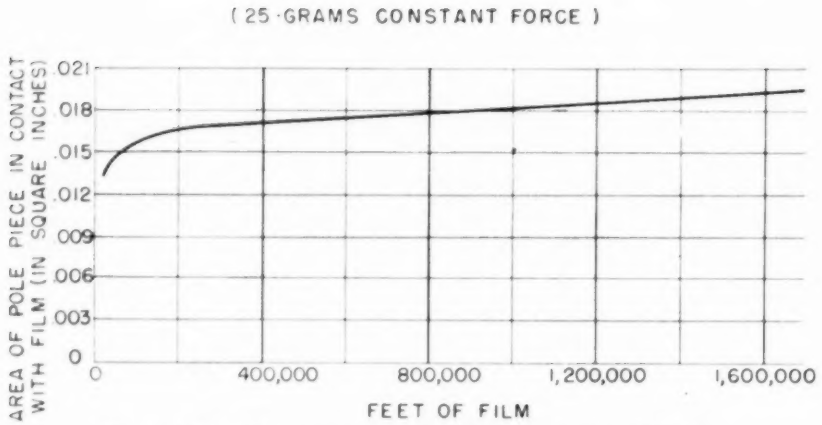

Fig. 3. Effect of wear on area of pole pieces in contact with film.

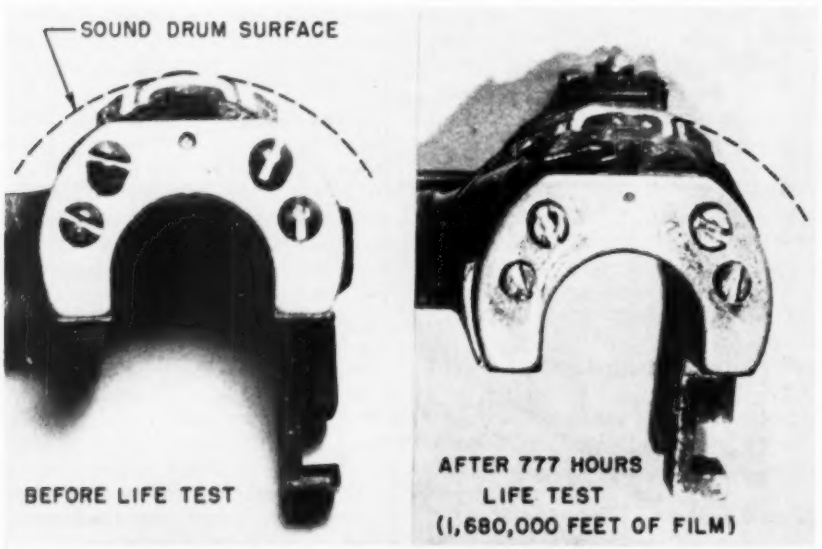

Fig. 4. Change of contour due to wear (25 grams constant force).

the curve shows relatively constant wear with respect to the amount of film passing through the projector.

The change in pole-piece area is shown in Fig. 3. This also shows the most rapid change during the first part of the test and very little change thereafter.

Figure 4 shows the wear of a head used in the tests. The dotted line represents the periphery of the sound drum.

The tests were not carried to destruction because it was thought advisable to retain the full performance of the head after running what was considered commercially satisfactory film footage.

Discussion

E. W. D'Arcy (De Vry Corp.): That's the first real bit of valid information on the subject I've seen. One thing which occurs to me, however, is that in the case of a half-width magnetic stripe located either along the outside edge or the inside edge of a photographic sound track, it wouldn't take very long to wear the magnetic head down in contour to the point where it would lose contact with the magnetic material and be bearing only on the optical portion of the sound track. I note that you have five mils wear in the first 88 hours. This may point to a consideration which has been going through our thinking, and which has been brought up in Mr. Dimmick's Magnetic Recording Subcommittee, as to the advisability of having half-track heads narrower than the magnetic tracks so they would wear uniformly. This would involve committing ourself to locating such tracks always on the same edge of the photographic sound track. What are your comments with regard to such a plan?

Mr. Ferber: With regard to using a half-track on the full-track width head, the maximum deterioration in output level you could get would be 3 db, due to the half-track. The problem in general could best be solved, of course, by using a harder material for the head, and that is being investigated.

Mr. D'Arcy: No, that isn't exactly the point. Using a full-track head on half-tracks always positioned the same, it would appear that it would take a relatively small time to wear a groove into the head which would react as, you might say, does a depth ball in disk recording, with the smooth or unworn part of the head bearing against the uncoated portion of the sound track, or against the film base itself, and the other half *out* of contact with the magnetic material.

Mr. Ferber: That's right, but since there is magnetic coating on both sides of the sound track, shifting from one to the other would only cause the loss in output level. Or going from a head that is worn with a half-track to a full-track head, you would have that same 3-db loss.

M. G. Townsley (Bell & Howell): I'd like to make a comment here in answer to yours, Mr. D'Arcy, if I may. I think your fear that the magnetic material will lose contact with the head if you continue to run half-track located, say, on the outer edge of the film, is based on the assumption that the head is not worn by the film base itself. Some preliminary results from tests we have run indicate that this is not the case, and that while there is some small stepwise wear initially, it isn't very long before the film starts to wear the head down too. The head continues to wear down with a small step, but both "treads of the stair" come down together. We are currently on one test which has involved up to 300 hours of half-track operation under very comparable conditions to those reported here. No serious deterioration in either the half-track performance or in full-track performance using the same head has been noted. That is encouraging.

Mr. D'Arcy: It should, but the fact remains that for films half-striped on the emulsion side, any very appreciable step-wear will very soon scratch the remaining photographic track so much that it becomes unusable, which is exceedingly serious considering the fundamental use possibilities for half-width magnetic striped. The point I'm making, and with this I'll withdraw, is that I believe these data certainly point out the need for special half-track heads, and for standardization of the positioning of magnetic half-tracks on photographic sound tracks so that head wear will not cause serious magnetic performance deterioration and possible serious damage to some original photographic sound tracks.

J. R. Horak (Eastman Kodak Co.): We have run 100-mil, 50-mil and 30-mil wide coating stripes of approximately 0.5-mil thickness down the centers of quarter-inch wide film strips. The strips were then run on an eighth-inch wide magnetic head. We found that the coating stripes do wear the head deeply enough so that small variations in the thickness of the coating and in its width cause changes in the coupling between the coating surface and the head, causing extreme amplitude modulation, and I mean considerably greater amplitude modulation than we would have on a smooth, well-polished head. This effect does occur, I think.

Mr. Ferber: I believe we have not experienced that condition due to the force applied to the head, forcing it against the film.

S. J. Begun (Clevite-Brush Development Co.): Perhaps I missed one bit of data which would have been important, namely, what was the force acting against the head which gave you this particular wear? I don't think you mentioned it.

Mr. Ferber: I didn't mention it, I'm sorry; but the figure was on one of the graphs. It was 25 grams of force between the head and the film.

Mr. Begun: Did you record all the other geometric relationships? I would also be very interested in getting the specific pressures under which you operated in the beginning, and maybe after limited wear took place, and subsequently.

Mr. Ferber: The machine is so set up that the force is constant and the unit pressure between the head and the film would depend on how far down the head is worn, because the contact area changes as the head wears as shown in Fig. 3. We have made no tests with different forces due to its taking 777 hours just to make one test, but undoubtedly work will be done along such lines in the future.

J. Kenneth Lewis (U.S. Navy, Bureau of Ships): Did you observe any noticeable wear on the narrow guiderail used to guide the film at the picture gate due to the magnetic track, which you say is quite abrasive.

Mr. Ferber: No, we didn't show any signs of wear at the gate, and of course there is none on the sound drum since the sound drum is narrower than the film itself.

George Lewin (Signal Corps Photographic Center): I would like to make one other comment which is directed to the manufacturers of the various striping methods rather than to the present speaker. However, wouldn't it be possible to add, while the stripe is being put on, some sort of a transparent material alongside the magnetic stripe which would not affect the photographic sound track, but would possibly equalize the wearing effect upon the head? Is that entirely ridiculous, or is it possible?

Mr. Dimmick: It sounds like a very interesting suggestion.

Edward Schmidt (Reeves Soundcraft Corp.): I don't suppose there's a direct answer to the question, except the fact that the cost of striping right now is being objected to in some quarters, and certainly any additional operation of the nature you propose would add to the cost.

Ernest W. Franck (Reeves Soundcraft Corp.): I think it would clarify the thinking somewhat if we think of the head wear as not being caused by the coating, but by the dirt, the abrasive dust which is picked up. The film base itself does considerable wearing for this reason — it picks up a lot of dust and dirt. Some types of coatings will pick up more dust or dirt than others and hence wear the heads more, but it's the dirt, more than the film base and more than the coatings, which does the damage.

A Study of Dropouts in Magnetic Film

By ERNEST W. FRANCK

Recording and playback losses caused by coating imperfections are evaluated quantitatively. A new technique is described, called "Micropolishing" which physically removes the mound or "nodule" type of imperfection.

THERE ARE so many ways in which magnetic sound tracks resemble photographic tracks that motion picture engineers have learned to use the new medium in a remarkably short time. One soon feels equally at home with a photographic slit or a gap in a ring-type head. Many problems, such as azimuth troubles, are common to both systems. In making photographic tracks, *sharp focus* determines resolution. In a magnetic system, resolution depends on *good contact* of the film with the record slit. In most parallels of this nature, the magnetic track is found to be less critical than the photographic, although there are some exceptions. Our present subject concerns one of these exceptions.

To show how *sensitive* a magnetic recording system is to small separations between the film and the heads, some measurements were made on a Westrex RA 1497 Recorder. Small nonmagnetic shims of various thicknesses were placed between the head gap and the film. This caused a separation between the film and the head equal to the shim thickness, and the loss for each spacing was measured.

Figure 1 shows the loss at various spacings up to 1 mil at a frequency of 7000 cycles/sec. The loss shown is the difference in playback level caused when the shim is in position and lifts the film from the head by the shim thickness. The lower line shows 7000-cycles/sec losses where the bias current is set to give peak 1000-cycles/sec response, in this case 20 ma. The upper line shows 7000-cycles/sec losses when the bias is increased to 33 ma and indicates a considerable reduction at the higher bias. At a spacing of 1 mil the increase in bias has reduced the loss from 30 db to 19 db.

In Fig. 2 are shown similar results at 1000 cycles/sec. The 1000-cycles/sec recording loss is seen to be the same as the 7000-cycles/sec recording loss in Fig. 1 when the bias current is 20 ma. The recording loss at 1000 cycles/sec is also

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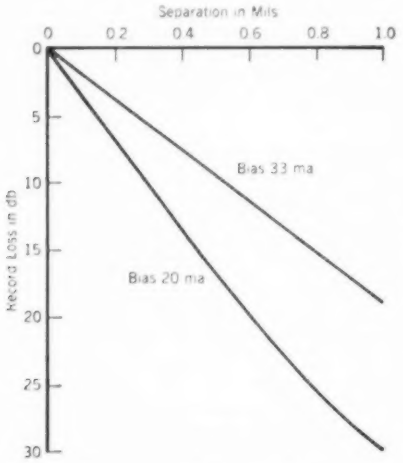

Fig. 1. Loss at various spacings up to 1 mil at a frequency of 7000 cycles/sec.

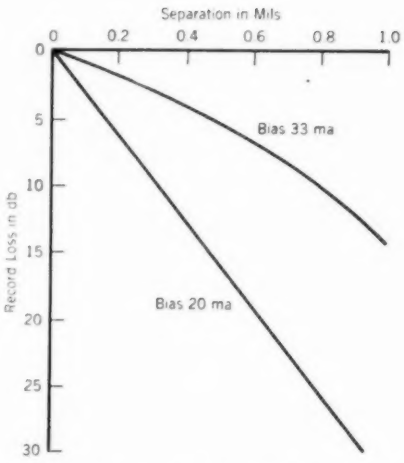

Fig. 2. Loss at various spacings up to 1 mil at a frequency of 1000 cycles/sec.

reduced when the bias current is increased from 20 ma to 33 ma. At this higher bias current the 1000-cycles/sec loss is less than the 7000-cycles/sec loss. The greater loss at the shorter wavelength is perhaps due to a loss of gap definition.

Similar measurements were made of the losses which occur during playback when the film is separated from the playback head by small distances. A constant level was recorded on the film, and the same nonmagnetic shims were used to separate the film from contact with the head by known distances. The results are shown in Fig. 3. It will be noted that the 1000-cycles/sec playback loss is comparatively small but the 7000-cycles/sec loss is large, as would be expected from the geometry involved.

If a magnetic film were to have some coating imperfection, such as a nodule, or a piece of embedded dirt, the film would lift from contact with the record head during recording and from contact with the playback head during playback with the result that the combined recording and playback losses are experienced. These losses, although of only momentary duration may be so large that they are very noticeable. A separation of 0.0003 in., for instance, will cause a loss of 11 db during recording, and an 8-db loss during playback at 7000 cycles/sec. when the bias is 20 ma (peak output at 1000 cycles/sec), or a total loss of 19 db. With the bias increased to 33 ma the loss would be reduced to only 11 db. Similar losses at 1000 cycles/sec would be only half as much because the playback loss is much less. With this sensitivity to separation of film from the head gap in mind it is easy to understand the severe requirements for flatness and smoothness of a magnetic track. Any small coating defect which lifts the film from the gap gives a momentary drop in output. This effect is commonly referred to as a "dropout."

It is fortunate that $\frac{1}{4}$-in. tape products came into general use before magnetic film products because a small coating imperfection causes much less trouble on thin, flexible tape base than it does on thick and comparatively rigid film base. The reason for the difference is illustrated in exaggerated scale in Fig. 4.

On the upper left of Fig. 4 is shown a section through $\frac{1}{4}$-in. tape as it passes

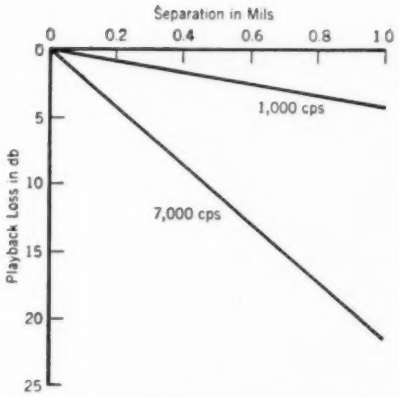

Fig. 3. Losses during playback with film separated from head by small distances.

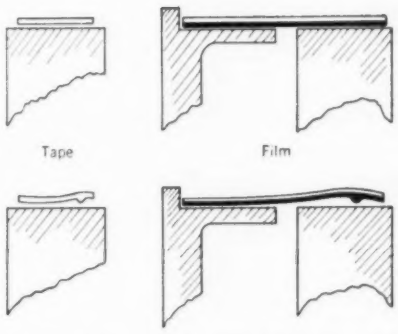

Fig. 4. Results with thin, flexible tape base and comparatively rigid film base.

over a head. If the coating is flat and free from bumps, good contact with the head is achieved. At the upper right is seen the film counterpart, with a flat, smooth coating in good contact with the head. The two lower views show what happens when there is a small bump in the coating. The tape, because it is more flexible is lifted from good contact *close to the bump only*, leaving other parts of the tape width in fairly good contact. The film, however, being too rigid to bend as the tape does, is lifted from the head over the entire track width.

A similar effect can be imagined along the length of the film with the result that the film, because of its rigidity, remains out of contact with the head *longer* than the more flexible tape whenever a bump passes over the head.

While in most uses of $\frac{1}{4}$-in. tape these "dropouts" are not troublesome, there are some tape applications where they are serious.

Telemetering applications, and applications using amplitude-modulated high frequency are sensitive to small dropouts which would not affect most audio work. Also, in computing machines where seven narrow tracks are used on $\frac{1}{2}$-in. tape to record binary system pulses, the tracks are so narrow that a bump like that shown at the lower left of Fig. 4 could cause complete loss of a pulse in one or even two channels, causing an error.

The need for good, uninterrupted head contact forced the manufacturers of magnetic products to take unusual precautions against dirt, undispersed clumps of magnetic powder, lint particles and the like. Enormous progress has been made during the past few years, as tape and film were used more and more in critical applications. Even after all dirt was eliminated, and special precautions were taken against dirt contamination in the coating process, there were still occasional dropouts. These were traced to a type of formation in the coatings usually referred to as "nodules." These are typically spherical in form and have no detectable nucleus. Unlike other defects which cause dropouts, they could not be filtered out — not because they were too small — but because they form in the coating during the drying process. Attention to drying conditions has helped to minimize them, but we have never been able completely to eliminate them, and have never seen any magnetic coating without them.

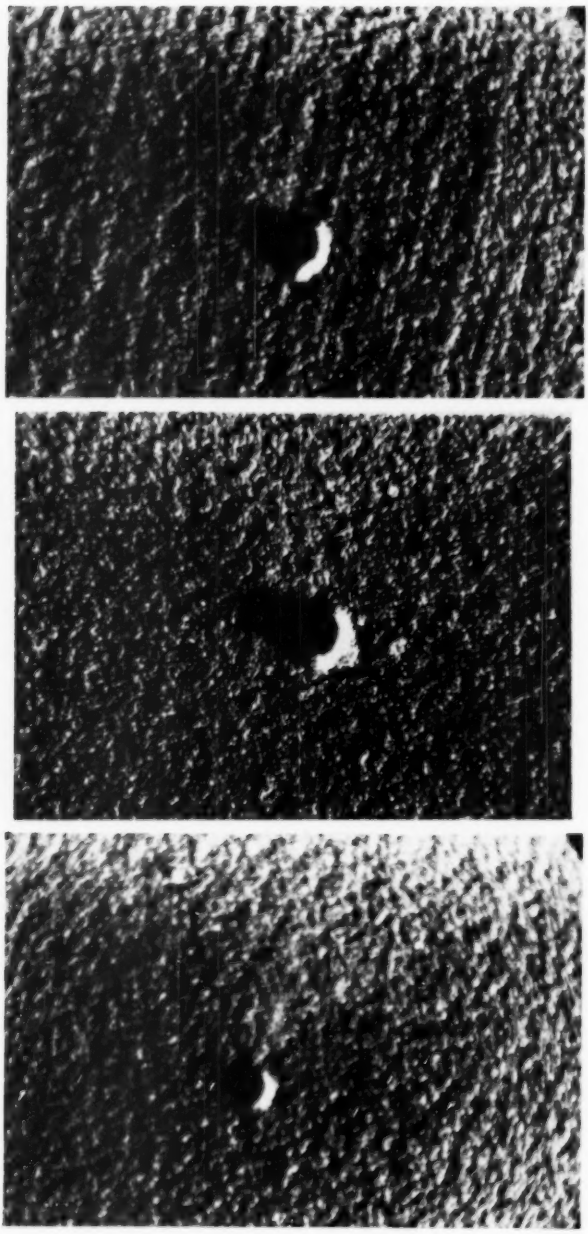

Fig. 5. Micrographs of nodules.

In Figures 5A, 5B and 5C are shown photomicrographs of this type of mound or nodule. They are lighted with grazing light to show relief, and are highly magnified. The nodule in Fig. 5A is about 3 mils across. The crescent-shaped reflection from the light at one side, and the shadow at the other, will indicate the elevation above the plane of the rest of the coating. This nodule is estimated to extend about 3/10 mil above the rest of the coating.

Some attempts were made to polish off these nodules by various means. High-speed brushes of horsehair, nylon, and even metal bristles were used with various stiffnesses, lengths and rotational speeds (Fig. 6). We were never able to get the brushes to polish down the nodules, since the contact areas were always too large.

We tried felt buffing wheels of various hardnesses as indicated in Fig. 7 and had slight encouragement with a hard felt at high pressures. While it was possible to reduce some dropouts this way it was found that after buffing about 1000 ft of film the felt would charge with some of the coating material and become useless. Also, the felt was likely to develop hard spots which would scratch the coating.

It was realized that any smoothing technique which would be effective in removing nodules would have to develop high mechanical stresses on the nodule without exerting high pressures on the rest of the coating. Attempts were made to do this using the basic principle illustrated in Fig. 8.

The film passes over the lower roller with the coated side up. This roller, which is hard and smooth, is about the size of a film stabilizer drum and is mounted in a rigid bearing. The film then bends around the idler and returns, passing over itself with the coated side down. As it passes over the lower roller, it is pressed downward by the spring-mounted upper roller so that two sections of the film moving in opposite directions are pressed into contact between the rollers. The upper roller is of a slightly resilient material so the pressures will be uniform over a narrow line of contact. When a nodule appears in this line of contact considerable mechanical work is done on it. Each nodule will be rubbed twice at each set of rollers. When the roller diameters, compliances, tensions and speeds are adjusted to the physical properties of the coating any nodule is very effectively polished off, leaving a flat surface.

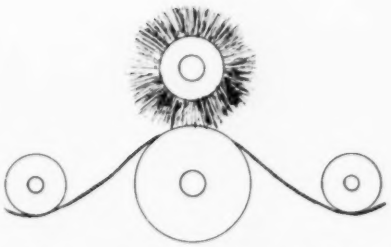

Fig. 6. Use of high-speed brushes for polishing nodules.

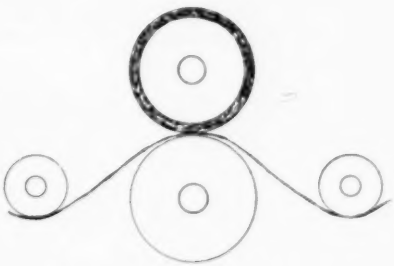

Fig. 7. Use of buffing wheels for polishing nodules.

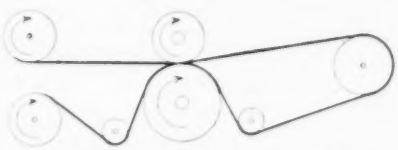

Fig. 8. Use of system for polishing nodules from film by self-rubbing action.

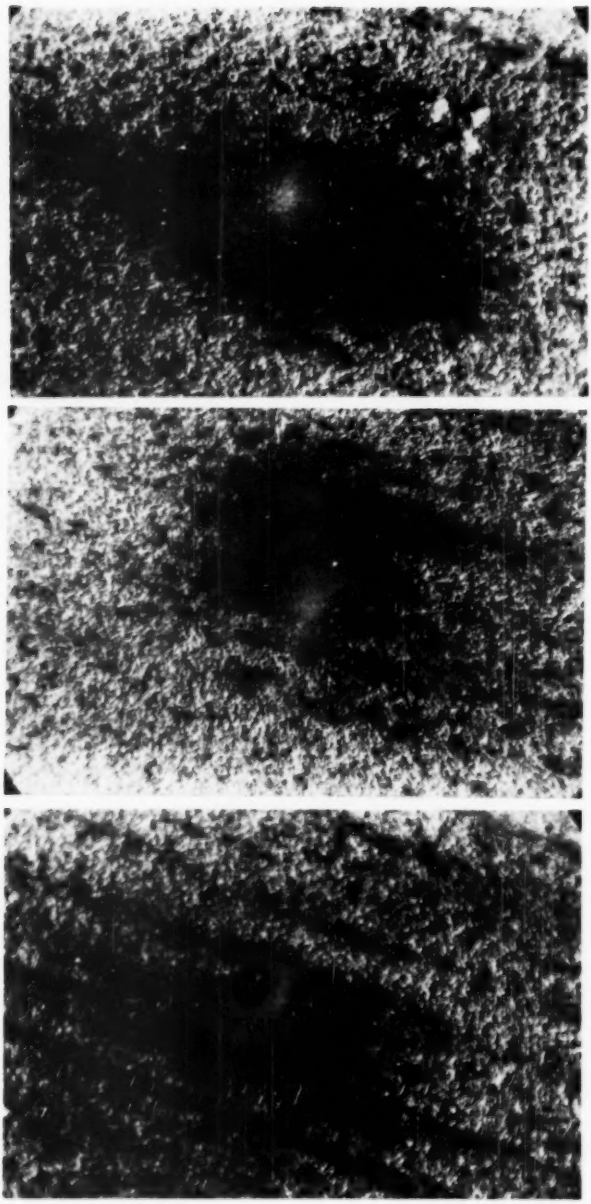

Fig. 9. Micrographs of film after levelling of nodules.

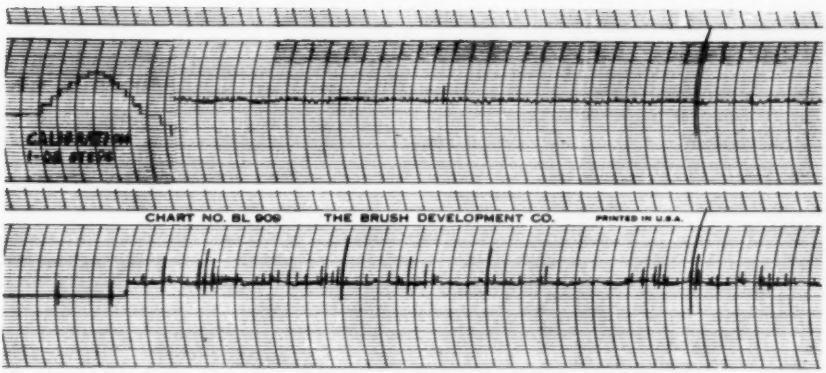

Fig. 10. Brush penmotor charts of film before (below) and after (above) micropolishing. Sharp spike at right is a reference mark common to both curves.

Figure 9 is a reproduction of photomicrographs of areas of film which show where the little hills have been leveled. Originally these had the globular appearance of the nodules shown in Fig. 5. The polished area is always irregular, and always very shiny as indicated by the glare areas. It will be noted there is no trace of shadow, showing good flatness.

Figure 10 shows some Brush penmotor charts of a length of film before and after Micropolishing. These charts were made by recording a steady 1000-cycles/sec tone, and then playing back into the penmotor. Whenever there is a momentary reduction in playback level it is indicated by the penmotor which responds very rapidly and shows changes in level of very short duration. This type of variation will not be shown by normal volume indicators. To make the test a severe one, the bias current was adjusted to give peak output. The lower part of Fig. 10 shows the dropouts present before Micropolishing* and in the upper part is shown the same film after Micropolishing. Although the process was developed primarily to combat nodules, it reduces the effect of other irregularities also.

This system has been in daily use for about six months and has resulted in a greatly improved product. Other benefits besides reduction of dropouts have resulted from the better head contact made possible. High-frequency response was improved by about 2 db at 10,000 cycles and there has been a marked reduction in intermodulation distortion.

Early in the work on combating dropouts a different approach to the problem was attempted. It was felt that for a time a softer coating should be less troublesome than a hard one, and that if a soft coating did have nodules they would be soft nodules. If the nodules were soft, they might wear off easily, hence there would be fewer dropouts. The first results were quite encouraging and an experimental program was laid out to determine how soft a coating could safely be. Before the program got very far, it was found that the softer coatings which had showed promise were no longer better than our regular material, and some actually were not even as good. It was then discovered that although they were kept in an air-conditioned area these special coatings

* This is the micropolishing process used by Reeves Soundcraft Corp. in making products bearing their trade-marks "Micropolished Film" and "Micropolished Tape."

had picked up enough dirt and dust particles to be more subject to dropouts than standard material which had the same handling. Embedded dirt is as likely to cause dropouts as coating nodules, and may even do more harm, because embedded dirt is abrasive.

A quick but very effective method of comparing the tendency of coatings to embed and retain dirt was developed. The two films to be compared are laid on a table, coating sides facing one another. Then some fine carborundum powder is dusted between them. We use a gray grit of about 400 mesh. Next, a cylindrical weight is rolled over the films, pressing the coated faces together. If there is any difference in dirt resistance, when the films are separated the grit will be found embedded in one coating, the soft one, while the harder, dirt-resistant coating will wipe off clean and smooth.

Much magnetic film goes into re-use applications, and it is suggested that for critical work, after the first use, the film should be carefully cleaned before re-use. The methods normally used for cleaning prints, such as passing the film over pads wet with carbon tetrachloride, are quite effective. Some users have hesitated to use any cleaning fluid at all, fearing that plasticizer would be leeched from the coating, but with Magna-Stripe this method is perfectly safe since the coating formulation contains no plasticizer.

In summation, we can say that in magnetic film applications dropouts can be troublesome if precautions are not taken. Attention should be given to two principal points: first, use of bias well above that for peak output; and second, taking care that the film used is smooth and clean.

Discussion

George Lewin (*Signal Corps Photographic Center*): I'd like to ask whether this process is now in use on film which is being released?

Mr. Franck: This process has been in use on full-width 35mm film and on 16mm full-width film for about six months.

Mr. Lewin: Is this process applicable to coatings which you put on raw film, and can you do all this polishing without damaging the film?

Mr. Franck: You mean after development?

Mr. Lewin: No, I mean prior to development.

Mr. Franck: No. The pressures required and all that handling — I don't think it would ever work out that way.

Otto Kornei (*Brush Development Co.*): You showed a number of curves indicating the recording and playback loss due to variable spacing. Could you elaborate a little bit on how you segregated the recording from the playback loss in the actual measurement procedure?

Mr. Franck: The recording loss was measured by placing a thin nonmagnetic shim between the film and the head to give a definite spacing. With the shim in place, there's a drop in recorded level which you measure by playing back. The playback level will be lower with the shim in place than when it is not, and this difference is what we refer to here as a recording loss. It is the loss which would take place at the recording head if the film had that particular separation. In the case of a small dropout, of course, it's just for a moment.

J. Clinton Greenfield (*Naval Photographic Center*): You mentioned a careful cleaning process in connection with the re-use of these materials. Would you comment on what you consider a careful technique with regard to solvents, etc.?

Mr. Franck: We have found it perfectly adequate to use carbon tetrachloride and to treat the magnetic film as if it were a print we were cleaning. It does a very good job, particularly on a very dirty film. A piece of film which has dropped to the floor, or which has had just normal handling in a dirty place, is charged with dirt which is very abrasive. This is, I think a very big factor in head wear. It is the charged dirt, either in the base or in the coating, more than the coating itself or the base when it's clean which does the wearing.

Robert H. Carson (*Naval Research Laboratory*): Could you hazard a guess as to

what percentage of the total dropouts are caused by these nodules or by actual defects in the tape, as against those which may occur randomly and cannot be tied down to any one section of the tape?

Mr. Franck: I think that *all* dropouts are caused by separation.

Mr. Carson: Yes, I agree with that, but I am wondering if you feel that they are all due to the actual coating surface.

Mr. Franck: Well, it can be anything which lifts the head off. It can be any irregularity in the film base which is bad enough.

Mr. Carson: What I am really trying to get at is whether you get any random occurrence of dropouts. Do you always find this same dropout occurring at the same spot in the film every time?

Mr. Franck: If we're very careful to keep the film clean and the equipment in a clean place, then we do. You can make a Brush High Speed Recorder chart showing where the dropouts are along the film. Then erase the film, re-record the same signal, and then make another Brush chart. They will overlap so much you might think one to be a carbon copy of the other. If you don't take precautions against dirt, however, you never will have two charts look alike. Dirt itself is as big a factor as the nodules I discussed.

Methods of Measuring Surface Induction of Magnetic Tape

By J. D. BICK

Of various indirect methods of determining surface induction, two are the subject of this discussion. Called the short-gap and the long-gap methods, they can be employed with any suitable magnetic recorder in the field.

THE SURFACE INDUCTION of a recorded magnetic tape is a quantitative measurement of the signal stored on the tape. More precisely, it defines the field of flux at the surface of the tape where it is available for reproducing with a conventional playback head and system. A frequency characteristic of surface induction defines the characteristic of stored signal on the tape. All tapes recorded with the same characteristic of surface induction will give the same results on any conventional playback system. Therefore, the frequency characteristic of surface induction is useful as a means for interchanging tapes with proper playback corrections, for evaluating recording and playback system losses, and perhaps as a means for establishing standards for the industry.

A disc recording with modulated grooves can be measured directly by optical means. Thus the amplitudes of signals recorded in sequence or in a glide can be measured giving the frequency characteristic of the record itself. This fact is very helpful to us in establishing standards both for recording systems and playback systems.

Unfortunately, a magnetic recording is more intangible. We have no direct means of quantitative measurement of the tape, especially at the shorter wavelengths. However, there are various indirect methods of determining the surface induction, two of which are the subject of this discussion. They are somewhat laborious to perform but they have one virtue at least. They can be performed on any suitable magnetic recorder in the field and are not merely relative measurements made on an arbitrary laboratory machine.

If we look at some typical curves of a magnetic tape recorder, it will become apparent how useful the surface-induction curve is. Figure 1 shows a set of curves for a typical RCA RT-11B tape recorder. The upper pair of curves shows the recording current pre-emphasis for each speed. The next pair of

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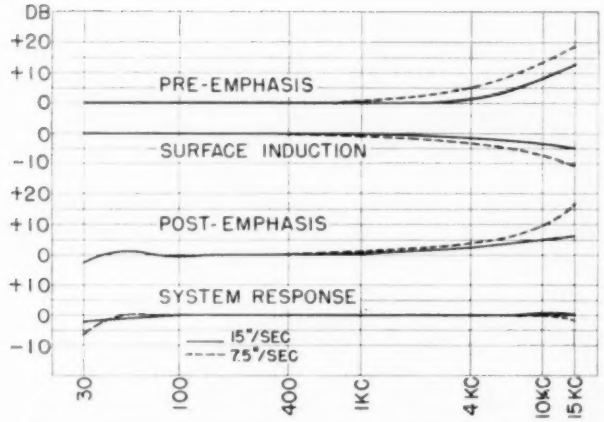


Fig. 1. Typical curves — RCA RT-11B Tape Recorder.

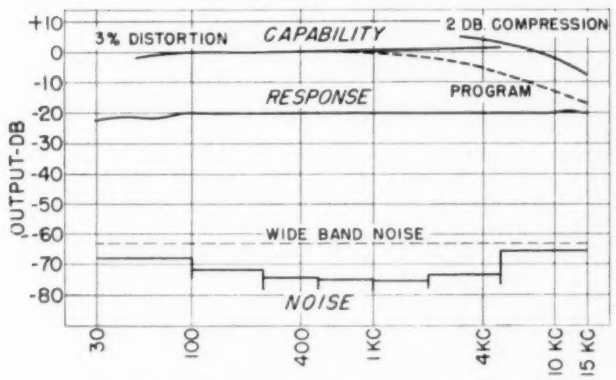


Fig. 2. Performance curves on the same RCA RT-11B as in Fig. 1, at 15 in./sec.

curves shows the surface induction for each speed; that is, the stored signal on the tape using this system. The next pair of curves shows the reproducing post-emphasis for each speed. These show the responses that would be obtained if the tape induced a constant current in the reproduce head. And finally, the lowest pair of curves show the overall system response from 30 cycles/sec to 15 kc for the two speeds.

Having the surface-induction curves, we can now evaluate the recording losses of the system as well as the reproducing losses. In the production of tape recorders, the losses vary somewhat in both recording and reproducing. But every machine is so adjusted that surface induction is the same, and overall response the same, only pre- and post-emphasis curves being altered to make up for these variations in losses. Therefore, tapes recorded on any machine can be reproduced on any other machine of this type with the same overall response.

In Fig. 2 we see a set of curves which

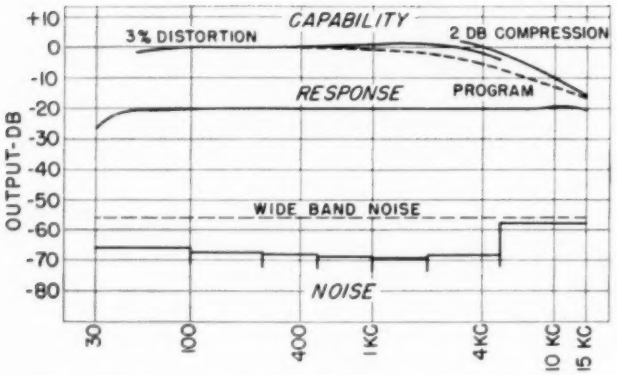


Fig. 3. Performance curves at 7.5 in./sec, corresponding to Fig. 2.

will explain further why it is important in a given design to adhere to a specific surface-induction curve. This shows the performance curves for the same RT-11B magnetic recorder at 15 in./sec. The flat system response is noted. A program distribution curve is shown for reference that is typical of peak levels contained in all kinds of program material including music and speech. This is the 75-μsec curve which is the inverse of the FM pre-emphasis curve. Above this is the capability curve of the recorder which is represented by constant 3% distortion at the low end and by tape compression at the high end. The 2-db compression curve is close to the knee of the overload point; that is, where a 1-db change of input causes a $\frac{1}{2}$-db change of output and is somewhat below saturation. It is seen that there is a wide margin between the program distribution curve and the capability curve at high frequencies. At the bottom of the figure is the noise curve. At any frequency, the dynamic range is the difference between noise and capability.

In Fig. 3, we have the corresponding performance curves at 7.5-in./sec speed. Again we have the flat system response. But now the margin between program distribution and capability has been reduced and the noise has come up somewhat.

Now as a practical matter in designing tape recorders, the noise is largely due to the reproducing system; and high-frequency noise can be reduced if we use more pre-emphasis. But then the capability curve runs below the program distribution curve which means that at high levels the highs become distorted or compressed sooner than the lows. Therefore, a given surface-induction curve represents a compromise which gives the best dynamic range with flat system response.

We must choose our surface-induction curves carefully with all this in mind and to take all other factors into account such as differences among tapes which exhibit various capability curves.

We have seen the usefulness of defining the surface-induction curves. Now, how do we get them?

Various laboratories have attempted some of the techniques of measurement used in the methods to be described. One of the methods was specifically proposed by P. E. Axon[1] of the BBC

[1] P. E. Axon, Research Dept., B.B.C. Engineering Div., "Overall frequency characteristic in magnetic recording," *B.B.C. Quarterly, V, No. 1,* Spring 1950.

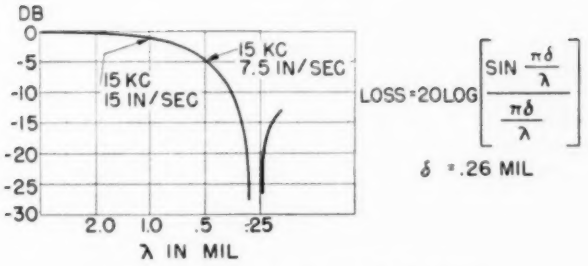


Fig. 4. Short-gap wavelength losses.

Research Department. The plan to use surface induction as a basis for standards was proposed first by the BBC and the Danish State Radio as participating members of the CCIR. Formulation of the specific procedure for the two methods of measurement is set down in the Danish report to CCIR[2] of February 1952. Since that time, participating members of the CCIR and NARTB have been attempting to verify the methods in an effort to arrive at standards.

The two methods which will be described here may be referred to as the short-gap method and the long-gap method. The methods have been named in this manner to distinguish them readily. In the short-gap method, a reproduce head is used whose gap length is short with respect to the shortest wavelength to be measured. In the long-gap method, the head gap is long with respect to the measured wavelengths.

The two methods will be described in turn, together with experimental results, and finally the results will be compared. The short-gap method will be considered first.

The short-gap method consists of calibrating a suitable reproduce system for losses and using the calibrated system to measure the output from a tape whose surface induction we wish to find. The method can be broken down into four steps: determining wavelength losses, measuring frequency losses, measuring the output of the tape to be evaluated, and computing the surface induction from the data of the first three steps.

In the experiments, a typical RT-11B reproduce head was used and connected open circuit to a relatively flat amplifier. This system was used for all measurements. In practice, an equalized system could be used as well, provided computations were all made to take this into account.

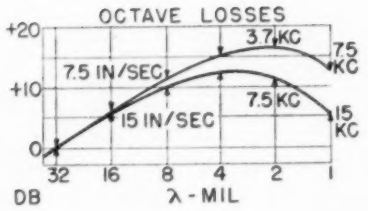
The wavelength losses due to the gap effect were determined first. The gap loss is assumed to follow the equation

$$\text{Loss} = 20 \log \frac{\sin \frac{\pi\delta}{\lambda}}{\frac{\pi\delta}{\lambda}}$$

where δ is the effective gap length and λ the wavelength of recorded signal. Figure 4 shows the loss curve with its null at the frequency where $\delta = \lambda$. The method of determining wavelength loss consists of measuring δ and computing the losses from the equation. By definition δ is equivalent numerically to the wavelength of the recorded signal at which the null occurs.

In the experiments the tape was run at a speed of $1\frac{7}{8}$ in./sec, and the output of the reproduce system was explored with respect to recorded frequency. A distinct null was located at 7100 cycles/sec from which an effective gap length of 0.26 mil was computed. In locating

[2] CCIR Question 63, Denmark, 2-28-52, I.T. No. 2022.



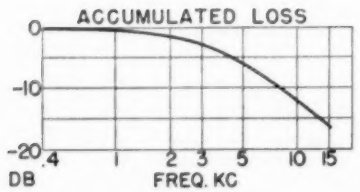


Fig. 5. Frequency losses.

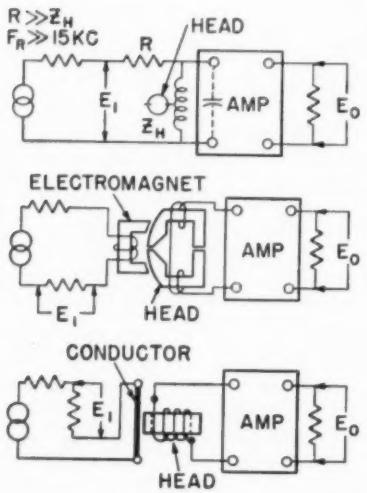


Fig. 6. Circuits for approximating frequency losses.

the null, it was found helpful to use filters in the output and to reduce the bias to a low value in order to reduce the recording losses. Complete removal of the bias, however, led to a false null at 2500 cycles/sec which is believed to be due to the geometry of the record head.

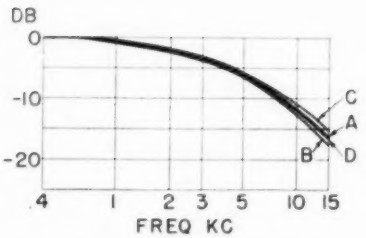


Fig. 7. Frequency losses by four methods; see text.

Having the value of δ the wavelength losses at the speeds of 15 in./sec and 7.5 in./sec were computed from the equation. The equation is probably valid in this case because a distinct null was obtained. Therefore, the edges of the gap were reasonably parallel and the tape was in good contact with both edges. The accuracy of the equation with variations in gap geometry is greatest when the loss is small. At $\frac{1}{2}$-mil wavelength, the computed loss is not more than 5 db.

The next step in calibrating the reproduce system consists of measuring the frequency losses. In the experiments, four different methods were used to measure this with substantial agreement between them. One method used tape and the others were electrical.

The first method using tape may be referred to as the change-of-speed method. A series of wavelengths were recorded and then played back through the system to be calibrated at speeds of 15 in./sec and 7.5 in./sec. The outputs at corresponding wavelengths were noted, and a correction of 6 db was added to the readings at the lower speed to make up for the fact that the rate of change of flux for each wavelength was one-half that of the same signal at the higher speed.

In Figure 5, the upper curves show the output obtained at the two speeds for corresponding wavelengths with correction of +6 db added to the 7.5-in./sec curve. The difference between the

curves represents the octave loss at each frequency since the speed change was a factor of 2. The total accumulated loss of a given frequency represents the sum of losses for all octaves down to the point where the curves coincide. For example, the accumulated loss at 15 kc equals the sum of losses at wavelengths 1, 2, 4, 8, etc., mils. This accumulated loss thus obtained at all frequencies is shown in the lower curve.

This method of measuring frequency loss has the advantage of using tape directly but has the disadvantage of accumulative error as well as somewhat unsteady readings at shorter wavelengths.

A variation of this method could be used in which the speed is made continuously variable over a wide range. However, this is not available on machines in the field whereas most machines have two speeds.

There are various electrical methods of approximating these frequency losses. Figure 6 shows the circuits for three of them. One method is to feed a constant current source through the playback head and measure the output of the system. The voltage across the head approximates the condition of induced voltage produced by a flat surface induction of the tape but with no wavelength losses. However, the flux path is not the same as it would be from tape since all of the flux passes across the front gap where different frequency losses may be found. Also care must be taken to prevent resonance of the head within the frequency range of the measurements since this would cause incorrect evaluation of frequency losses.

Another method which is perhaps more accurate (in that the flux path in the head is the same as it would be from a recorded tape) is the use of an electromagnet placed across the head gap. In this method we have in effect a stationary magnet of fixed wavelength whose strength varies in frequency. This method to be accurate requires evaluation of frequency losses in the electromagnet itself.

The last method also makes use of a stationary magnet of fixed wavelength and variable frequency across the gap. In this case, a conductor is placed parallel to the gap; a constant current passing through the conductor produces a constant induction. The conductor used was a brass strip of greater width than the length of the gap.

The four curves in Fig. 7 show the frequency losses of the system obtained with all four methods. The A curve shows the losses measured by feeding constant current through the head, the B curve shows those measured by the electromagnet method, and the C curve shows those measured by the conductor method. The B curve was corrected for electromagnet losses.

The D curve shows the losses measured by the method which uses tape at variable speed. This curve agrees very closely with the A curve. In fact, the curves all correlate within ± 1 db. The D curve was used to calibrate the system for the curves to be shown later.

The reproduce system has now been calibrated and the wavelength losses and frequency losses have been measured separately. The next steps can now be taken; measuring the output of the unknown tape and computing the surface induction by correcting the output for those losses. In this case, the tape used in the experiment was a recording having the standard characteristic for the RCA RT-11B tape recorder at 15 in./sec and 7.5 in./sec.

Figure 8 shows the resulting surface induction at the two speeds. The lower curves at each speed show the output of the system which has been graphically corrected by 20 db per decade. The dotted curves show the outputs corrected for frequency losses and the upper curves are corrected for frequency and wavelength losses, giving the resultant surface induction.

It should be noted that an additional

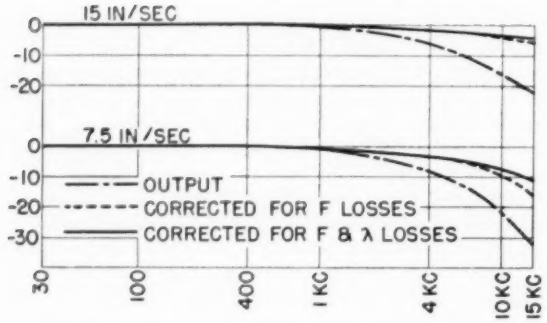


Fig. 8. Short-gap surface induction at the two speeds.

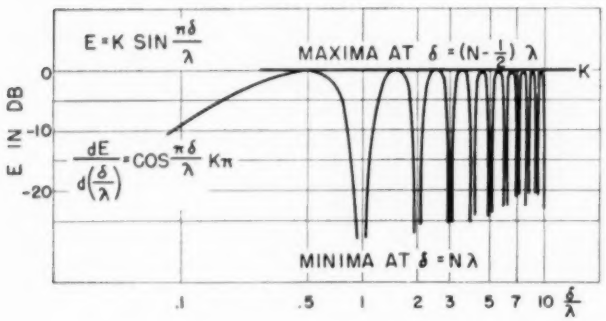


Fig. 9. Theoretical long-gap output.

wavelength loss of the order of ±1 db was found at the extreme low-frequency end of the output curve. This could have been measured by using very low tape speeds. Actually, it is fair to assume in this region that the surface induction is proportional to recording current.

The long-gap method of measuring surface induction also consists of calibrating a reproduce system, but in this case a playback head is used that has an effective gap length which is long with respect to the wavelengths to be measured.

An ideal long-gap head connected open circuit and with constant induction has a voltage output with alternate maximum points and nulls. The output curve is assumed to follow the equation:

$$E = K \sin \frac{\pi\delta}{\lambda}$$

as shown in Fig. 9.

The constant K includes the surface induction, the gap length and the speed of the tape. From the equation

$$\frac{dE}{d\left(\frac{\delta}{\lambda}\right)} = K\pi \cos \frac{\pi\delta}{\lambda}$$

The maxima occur when $\delta = \frac{1}{2}\lambda, \frac{3}{2}\lambda,$ etc., or when $\delta = \left(n - \frac{1}{2}\right)\lambda.$

The minima occur when $\delta = n\lambda.$

The value of E at the maxima equals a constant. Therefore the locus of maxima with an ideal head is a straight line and flat. This line represents surface induction directly.

A nonideal head together with its amplifier will have a locus of maxima other than a straight and flat line. This is due to frequency losses which can be corrected and secondary wavelength

losses which cannot be corrected at the present time.

It is to be noted that surface induction is measured by this method at discrete frequencies only; i.e., the frequencies where the maxima occur. Also the lowest frequency measured is that of the lowest maximum. Therefore, the long-gap method is concerned with middle and high frequency measurement only.

The long-gap method can be divided into three steps: measuring frequency losses, measuring the output of the tape to be evaluated, and computing the surface induction from the data.

In the experiments, a long-gap head was made and connected open circuit to a relatively flat amplifier. The head had a gap length of 18 mils which caused the maxima to lie approximately 1 kc apart at 15 in./sec. A considerable effort was made so that the edges of the gap were as nearly parallel as possible. Actually three heads were tried, the data showing the results of the best one in this respect.

In the first step, the frequency losses can be measured by any of the methods described for the short-gap method. In the experiments the change-of-speed method using tape was used exclusively.

Figure 10 shows the octave losses as measured and the accumulated frequency loss as computed from the measured losses. In measuring the octave loss with speed change of two, a gliding tone was recorded in the region of each maximum so that suitable output could be obtained.

In the next step, the calibrated system was used to measure the output of a gliding tone on a tape whose surface induction was to be determined. The surface induction was known to be the same as that which was measured with the short-gap method so that a comparison could be made between the methods. This was insured by using the same record system and head, the same recording current characteristic and bias current, and the same piece of tape.

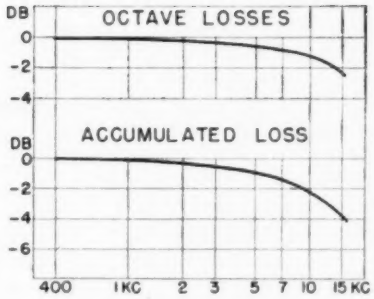


Fig. 10. Long-gap frequency losses.

The curves in Fig. 11 show the output at 15 in./sec corrected for the frequency losses. The heavy line drawn through the maxima is therefore the surface induction as found by this method. The locus of minima is shown indicating modulation noise below 3 kc and signal above 3 kc. The latter is due to incomplete cancellation because of lack of parallelism between the edges of the gap. This may cause a slight error in maximum readings. With an ideal head, the maxima would not fall off as rapidly at the high end.

Figure 12 shows similar curves taken at 7.5 in./sec of the surface induction at that speed. Again the output curve is corrected for frequency losses. Here the difference between maxima and minima is not more than 5 db at the shortest wavelength. The output of the system at the minima consists partly of noise but mostly of signal as determined by listening and by filtering. The accuracy of surface induction at the short wavelengths is obviously not very great with this head due to an imperfect gap.

The effect of parallelism between the edges of the gap can be illustrated in this way. The point where the maxima and minima converge represents an error in parallelism such that n wavelengths appear across one side of the gap and $n + \frac{1}{2}$ wavelengths appear across the other side of the gap. With the experimental head, it appears that convergence would

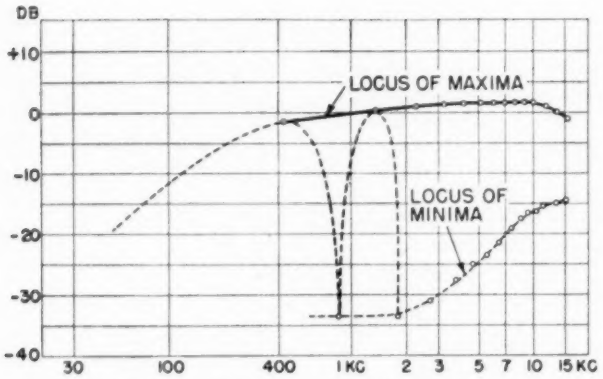


Fig. 11. Long-gap surface induction at 15 in./sec.

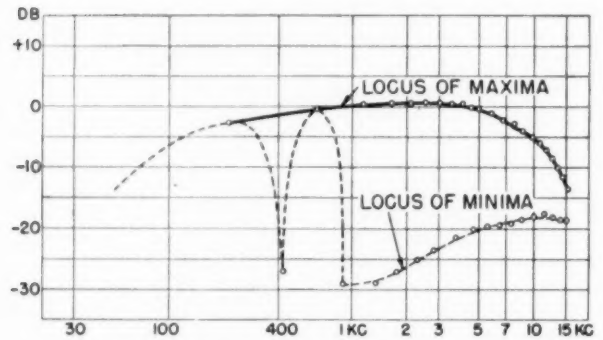


Fig. 12. Long-gap surface induction at 7.5 in./sec.

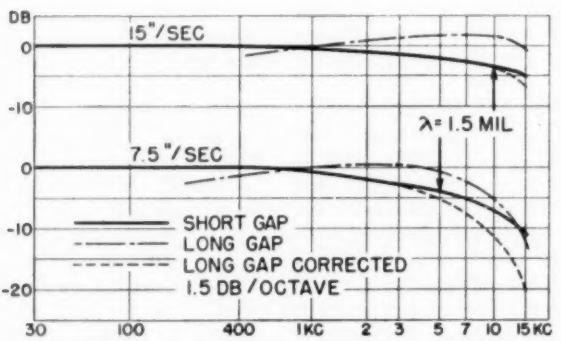


Fig. 13. Results of the two methods of measuring surface induction.

occur at about 0.4-mil wavelength or 40 wavelengths across one side of the gap and 40.5 wavelengths across the other side of the gap. This represents an angular error of 6 min and a linear error of 1.2% for the gap of the experimental head. Since this head is not suitable for measurement at $\frac{1}{2}$-mil wavelength, it is evident that a degree of accuracy is required which may not be practical to obtain.

The parallelism problem can be reduced in long-gap heads in various ways. For one thing, it might be advisable to have a series of heads of successively shorter gaps, placing the maxima farther apart at the high end but improving the accuracy. For another thing, the long-gap head could be made with a narrow track width so that for a given angular error in gap edges the linear error would be reduced. Neither method has been investigated prior to this paper.

A comparison of the results of the two methods of measuring surface induction is shown in Fig. 13. The upper set of curves shows the 15-in./sec surface induction, and the lower set shows the 7.5-in./sec surface induction. The solid curves are the short-gap method and the dot-dash curves are the long-gap method.

The most striking difference between the curves is a difference of slope of about 1.5 db/octave. A 2-db/octave difference was found by the BBC and the Danish participants in the CCIR. Various explanations have been offered for the difference in slope, and the matter is still under investigation.[3] It is apparent that there is a wavelength dependent variable that does not appear in the assumed equation.

The short-dashed curve shows a correction of 1.5 db/octave in the long-gap curves. With this correction, the curves fit closely to about 1.5-mil wavelength with the short-gap curves.

After this, the long-gap curves drop below the short-gap curves. It may be stated that measurements reported by the BBC and Denmark were only carried out to 1.5-mil wavelength. Up to this point they found the two methods to agree after applying the slope correction.

In conclusion, it is felt that it is desirable to be able to measure surface induction. With the information gained, it is easier to evaluate recording and playback losses of a system as well as to evaluate tapes. Furthermore, it is desirable to be able to make the measurements in the field and be assured of substantial agreement of these measurements with others made on other machines.

Methods are being devised for making the measurements. Of the two methods described in this discussion, the short-gap method is easier to perform and does not require a special head construction. Its accuracy is probably good if wavelength losses are held within 5 db. The long-gap method may be promising in the laboratory, but its accuracy must be improved at short wavelengths. Also we need to determine the nature of the 1.5 db/octave correction. Until this is explained fully, the validity of the long-gap method is questionable.

Other methods may be devised, and with them we may have further checks on our results.

The writer acknowledges the guidance and suggestions of W. E. Stewart, Chairman of the Subcommittee on Magnetic Tape Recording of the NARTB, and W. H. Erikson of Advanced Development Engineering, RCA Victor Div., as well as assistance in the project through design of special heads provided by L. W. Ferber of Commercial Sound Engineering, RCA Victor Div.

[3] Since presentation of this paper, the following publication has appeared which may contain the explanation of the difference in slope between the two methods: W. K. Westmijze, Philips Research Laboratories, Eindhoven, Netherlands, "Gap-length formula in magnetic recording," *Acustica, 2, No. 6:* 292, 1952.

Standardization Needs for 16mm Magnetic Sound

By ELLIS W. D'ARCY

Industry requirements for 16mm magnetic sound standards are outlined with respect to universal reproducibility, and test film needs for equipment manufacture and maintenance are described.

EVER SINCE ITS inception our Society has undertaken the responsibility of recommending standards for the motion picture industry. This has been one of the major constructive actions by the Society aiding the motion picture art to reach its present stage of technical quality. These standardization actions also are very helpful in introducing new developments into the motion picture field, thus enhancing the existing film technique. The Society's standardization activities are therefore an indispensable motion picture industry function.

It should be of value here to review briefly how standards and recommended practices are established. The full procedure was published on page 155 of the August 1952 *Journal*.

Presented on October 10, 1952, at the Society's Convention at Washington, D.C., by Ellis W. D'Arcy, De Vry Corp., 1111 W. Armitage Ave. Chicago 14.
(This paper was received on December 18, 1952. Because of its coverage of standardization, it was reviewed not only by the Board of Editors but also by the Sound Committee and its Magnetic Sound Subcommittee. It was approved for publication on February 20, 1953.)

Any request to the Society for a standard is referred by the Society's Engineering Vice-President to the responsible Engineering Committee, with a recommendation for action. Upon consideration by the committees, the proposal, if approved, is transmitted to the Society's Standards Committee which passes on the findings of the respective Engineering Committees before recommending *Journal* publication for trial and criticism. Subsequently, a proposed standard is transmitted to the American Standards Association for final issuance as a motion picture standard. Specifically, with respect to magnetic sound for motion picture use, the responsibility for magnetic standards has been assigned to the Sound Committee of which John Hilliard is now Chairman. A Magnetic Sound Subcommittee has been established to deal specifically with magnetic sound on film. Glenn Dimmick is Chairman of this Subcommittee.

The determination of electrical reproduction characteristics has been assigned as a single problem to a Subcommittee of the Magnetic Sound Subcommittee. This task committee has the responsibility of making for magnetic sound a recommendation similar to that

now issued by the Society for 16mm optical photographic track. The responsibility for the formation and action of this task committee has been assigned to the writer.

A standard, therefore, has to be approved by the designated Engineering Committee and the Standards Committee before the transmittal to the American Standards Association for final action. Also publication in the *Journal* for comment is mandatory before final approval. Differences of opinion are reconciled within the Society before releasing a proposed standard to the A.S.A. Where a need exists for an industry understanding which cannot be resolved as a standard, a second and less binding action is taken, that of publishing an SMPTE Recommended Practice, which allows further study to be made of the potential standard before final acceptance as an American Standard.

Standardization for any sound track may be divided into three interrelated actions. These, in the case of magnetic sound track, are:

A. Dimensional Standards

1. Dimension of coating and placement
   (a) Full-track (100-mil) and placement
   (b) Half-track (50-mil) and placement, etc.
2. Distance between picture and matching sound
3. Side of film to which coating will be applied.

B. Electrical Performance Standards

1. Frequency characteristics of reproduction
2. Intermodulation distortion film

C. Test Film Standards

1. Multifrequency test film
2. Speed steadiness film (flutter test film)
3. Azimuth film
4. Buzz-track film
5. Magnetic head contact film

Action has been taken on all of the preceding by committees of the Society although some time is involved in finalizing an end solution to each of the items listed. Current status is as follows:

A. Dimensional Standards

1(a) *Physical dimensions and location of full-track (100-mil) magnetic coating on 16mm film.* The Society's Committees have agreed to the dimensions and placement of full-track magnetic coating and action is now proceeding to formalize these understandings into a standard (PH.22.87, published in the July 1951 *Journal* for comment).

1(b). *There has, as yet, been no decision reached as to preferred location of magnetic half-track (50-mil).* The present situation is predicated upon the existence of a great quantity of photographic sound-track prints whereon the sound track has not been positioned accurately. This requires the magnetic striping to be placed over the photographic sound track in a position dictated by the off-substandard photographic track.

2. *Distance between picture aperture and point at which magnetic track is scanned.* This standard has been agreed upon and is now in the formalizing process of committee and is 26 frames between picture and matching sound.

3. *Side of film to which magnetic coating will be applied.* Due to the need for both photographic and magnetic reproduction facilities in the same equipment, and consequently the mechanical positioning needs for the two systems, it has been decided that the magnetic point of pickup of sound would be located opposite to the slit system and exciter lamp. (Normal placement of magnetic sound track on film shall be considered as on the side of the film surface facing the projector lamp.)

B. Electrical Performance Standards

1. *Frequency characteristics of reproduction.* 16mm magnetic sound has up to the present time been largely of a dictating-machine character in which the sound is recorded and reproduced on the same machine. This situation leaves the exact record characteristic up to each individual manufacturer since a complementary reproduce characteristic can be incorporated in such individually manufactured equipments. A situation of this kind is entirely unworkable on an industry-wide basis, since here a common understanding must exist in order to produce magnetic prints in laboratories for widespread distribution and reproduction on a wide variety of reproduction equipments. This situation is directly analogous to that existing in the production of normal 35mm film, and subsequently applied to 16mm photographic sound prints. This method of approach to the control problem is described in the Society's Tentative Recommendations for 16mm Review Rooms and Reproducing Equipment (pp. 116–122 of the January 1951 *Journal*).

Briefly, the control now effective in the production of sound film does not specify the recording characteristic but does specify the reproduction characteristic, thus leaving the exact recording technique to the individual producer or equipment manufacturer.

Such a method of control requires the production of a test film of known absolute values of discrete test frequencies.

The methods for measuring such a magnetic film have not been evolved until recently* so that effective control of universal reproducibility of magnetic sound could not be established. These techniques are now being studied through the actions of the Society's Sound Committees, more specifically the efforts of Dr. John G. Frayne of Westrex Corp.

An engineering task group has been appointed by Glenn Dimmick to effect compromises of such equipment variances as may currently exist and to make a recommendation similar to that presently existing for 16mm photographic sound track and published as Tentative Recommendations for 16mm Review Rooms and Reproducing Equipment, cited above.

This recommendation will not restrict the frequency range of magnetic sound track to that presently acceptable for photographic sound track. The actions proposed will not merely meet the immediate industry need for common action, but rather will anticipate the time when magnetic track may replace photographic sound track for highest quality reproduction purposes.

The industry's need for early action is realized by all members of the task group and it is anticipated that a recommendation will be prepared for Sound Committee action by May 1953.

It does not follow that industry needs will have to await upon such a formalization since the committee membership is comprised of sufficient representation to allow immediate application of committee findings to the current problems.

2. *Intermodulation distortion film.* In order to establish sound reproduction listening conditions it is essential that there be a method of checking the reproducer and associated electronic amplification system as to freedom from distortion. This can be most conveniently done by an intermodulation test measurement.

Film for this purpose has not been produced as yet, although methods for the production of it are now being considered by the Society's Sound Committee. This is an open item.

C. Test Film Standards

1. *Multifrequency test film.* This interlocks directly with item B,1, above — characteristics of reproduction. Such

* J. D. Bick, "Methods of measuring surface induction of magnetic tape," in this *Journal* on pp. 516–525.

a test film could not be produced until a method of direct calibration could be evolved. This has been accomplished, and the Society will presently be circulating several of these films to the various equipment manufacturers for their use in establishing the frequency-response characteristics of the various magnetic sound projectors. This film will be made available through the Society's test film production activities.

2. *Speed steadiness film (flutter test film).* This test film is essential for the evaluation of projector film speed steadiness at the point at which magnetic soundtrack scanning is accomplished. Specifications have been prepared for its production.

3. *Azimuth film.* Magnetic sound on film is produced by moving the film over a magnetic gap of very small length. This gap must be aligned at right angles to the edge of the film within a very close tolerance. Each projector should be aligned from accurate standard azimuth film in order that the high-frequency end of the audio spectrum may be reproduced well by projectors other than that on which the film is originally recorded. Production of such a film is essential before anything other than the dictating-machine concept is practicable. Two types of such film have been authorized by the Society's Sound Committee.

Type A: 7000-cycle film accurately positioned to within three (3) minutes of arc with respect to a line perpendicular (90°) to the edge of the film. Used basically for magnetic head alignment in projectors.

Type B: 7000-cycle film, multi-azimuth and off-azimuth film, produced to check the accuracy of the azimuth setting of magnetic heads in projectors. This will be a service test film used for locating trouble; whereas the type A, azimuth film, is a production tool used for the alignment of magnetic heads.

Both of these films are to be produced and issued by the Society as rapidly as the production technique involved can be solved.

4. *Buzz-track film.* This is essential in the correct positioning of magnetic heads with respect to the magnetic track. This test film is still awaiting a solution as to its fabrication.

The exact method of producing such a film has not been determined as yet and Society action will have to await a practical proposal to accomplish the desired end result. This problem is now being considered by the Society's Magnetic Sound Subcommittee.

An estimate cannot be made at this time as to the film's availability.

5. *Magnetic head contact film.* Magnetic heads are aligned in contact with the film, at this time, by a process of applying machinists bluing to the magnetic head and adjusting the head so that the bluing is wiped off the gap face uniformly across the head width. This is an extremely laborious operation. Alignment film for field service will have to be produced to meet this need.

No recommendation for such a film has been made as yet, and the problem may be left to the individual manufacturers to solve, since the film will be a production service tool and does not pertain to basic magnetic track quality testing.

It will be apparent from the preceding that the establishment of quality standards and the producing of test films to measure those standards is quite a project.

The situation might be summed up this way, which goes first, the cart or the horse. Applying this old cliché to the current situation, without the pioneering spirit exhibited by a few of the equipment manufacturers the need would not exist for the Society's standardization activities with respect to magnetic sound. Therefore, since 16mm magnetic sound track is so recent it is understandable that so many pertinent engineering factors have not been reduced to common understandings through standards. The writer can, however, report that

in his opinion rapid progress is being made by the various Society Committees and their actions certainly auger well for the future of 16mm magnetic sound recording and reproduction.

Editorial Note

The foregoing paper originally included between the present B-1 and B-2 sections several paragraphs discussing production techniques for magnetic standard signal-level test films. During review of the paper by members of the SMPTE Sound Committee and Magnetic Sound Subcommittee it became apparent that this discussion needed modification to bring it into agreement with certain considerations which have developed since the paper was presented. Inasmuch as Dr. Frayne has been very closely connected with these, Mr. D'Arcy and he agreed that the original paragraphs should be deleted and the following addendum, prepared by Dr. Frayne, be published:

Standard Magnetic Signal Film. The recording and calibration of a standard signal-level photographic sound track have constituted a very valuable adjunct in the lining up of photographic reproducers, and it is thought that a similar magnetic standard signal-level film would also be of equally great value. Methods of calibrating a standard signal photographic level film have been developed over the years, and there is quite general agreement now as to the interpretation of such films. The production of such a film on a magnetic medium is in itself rather simple, provided certain parameters are specified. If, for example, a 1% distortion is considered a desirable maximum recording level, then it is a relatively simple matter to record a standard frequency at 400 or 1000 cycles which would on reproduction show a distortion of this amount. There are, of course, various ways of arriving at such an overall distortion, the final result depending on such things as the amplitude of the high-frequency bias and the input level to the head. However, these recording techniques are now quite well established in the motion picture industry, and there should be no problem to making such a film to meet the 1% distortion specification.

If the absolute level in terms of magnetic induction of such a film is desired, this can also be obtained using some of the calibration techniques currently under consideration. It is doubtful, however, whether an absolute calibration is desirable in terms of units of magnetic induction since it would mean very little to the user of this film under practical testing operations. Possibly such a master film could be made and retained by the supplier of the test films — the thought being that the production test films could be calibrated against this master film.

Discussion

George Lewin (Signal Corps Photographic Center): At the meeting of the Magnetic Sound Subcommittee earlier in the week I made a remark, more or less with tongue in cheek, which perhaps I should repeat, now that possibly representatives of all four of the major producers of magnetic striping are present. The remark was that it doesn't seem entirely impossible that magnetic-striping material could be made transparent or semi-transparent, in which case you could always make it full width and thus eliminate most of these problems we have about half-track versus full-track.

Mr. D'Arcy: May I suggest that that be answered by some of the striping people here?... No response?

Mr. Lewin: The fact that one of them has announced an oxide which seems to be 10 or 12 db more sensitive may indicate they could afford to disperse the particles a little bit more and give up some of that sensitivity in the interest of making the coating transparent.

Mr. D'Arcy: Would you like to answer that, Dr. Wetzel?... No, I don't believe Dr. Wetzel has an answer to this suggestion at the moment.

Maxwell A. Kerr (Bureau of Ships): It has just occurred to me this afternoon that perhaps we have a blessing in disguise in the practices discussed earlier about the location of magnetic half-width stripes on photographic sound tracks. If by chance or by deliberate planning we regularly alternate the half-width stripe position, head wear would be equalized by the general use of various films, so why standardize on just one side for half-track? We have recently been informed by one organization doing striping that half-

width stripes are being alternated in position from film to film for this purpose.

Mr. D'Arcy: I have an answer to that one. We have applications which involve continuous loop projectors, which are used extensively by educational and commercial people. In such cases head wear occurs always on the same side, though of course there is some possibility that the striping could be alternated in position within the loops.

Mr. Kerr: It might even be sufficient for the manufacturer of such film loops to alternate the striping on the prints, and then just interchange prints once a week or so depending upon hours of operation.

William H. Unger (Elliot, Unger & Elliot, Inc.): We produce commercials for television. I've been very interested in the discussion this afternoon because we would like to do something to improve the sound quality on 16mm release prints, but as far as I can see, the solution, as far as we're concerned, is still to be found. There are several problems that I feel the various SMPTE subcommittees should possibly consider in more detail.

Mr. D'Arcy: What is the first major problem you foresee?

Mr. Unger: Well, there's a considerable problem during, first of all, the interim period. The TV stations, of course, are now all equipped to run photographic sound tracks. We'd like to supply them with magnetic tracks. What happens when you have a magnetic track spliced in with some photographic tracks? No consideration has been given to this. There are certainly going to be a lot of producers who will be supplying photo tracks. If we went ahead and supplied magnetic tracks, even if the stations were set up to run them, when you get a 20-second spot spliced into the middle of a reel of other material to make a half-hour or a fifteen-minute show, including station break, a one-minute commercial, and the 20-second commercial, if that one 20-second commercial happens to have a magnetic track on it, there's an awful chance that it is going to get lost in the shuffle because somebody will forget to throw a switch.

Another problem: It was reported this morning, by Westrex, that 200-mil push-pull variable-area photo tracks could be used and suggested that you could print off one half of them. Actually we have been using such tracks and we do make our release prints from one half of them. There's a tremendous advantage to us in doing so because we record push-pull negative. This is a little unconventional, I realize. We make push-pull positive prints and then edit these tracks, which gives us good prints for re-recording and also gives us a safety factor. These films are handled a great deal; if a print becomes scratched or dirty, it's very simple to make a second print and match-cut it to always have a clean print for re-recording purposes.

Mr. Dimmick: I am sorry to interrupt you, Mr. Unger, for your discussion is very interesting and I wish we could continue. We are a good deal over our allotted time in this room, however, and must close both the session and the convention. I suggest you outline the problems, and any suggestions you have, in a letter to me for consideration by the Magnetic Sound Subcommittee of the SMPTE Sound Committee. We thank Mr. D'Arcy for his very fine presentation. Also I thank all of you present for attending our symposium and for your expressions of interest in these very timely subjects.

Editorial Note

Mr. Unger subsequently submitted the following additional comments to conclude his discussion.

The problem I was about to outline concerning our method of making release photo tracks from one half of 200-mil push-pull original variable-area tracks is that it is not possible to half-stripe them (to provide both photographic and magnetic reproduction from the same film) because the release tracks are unilateral. A somewhat similar situation prevails in the case of conventional 100-mil bilateral variable-area tracks. Unless the half-striping exactly splits such tracks, severe distortion may result in reproduction of the residual photo track. It has been our experience that nearly all reduction printers produce some sound-track weave; unless the magnetic half-striping follows this weave very closely, the remaining photo track may become practically useless.

The problem of differential head wear using magnetic tracks of less than "standard" width has already been discussed. We feel that it is a very serious one which

must be fully resolved before standardization of magnetic tracks for TV station use can be accomplished. As has been pointed out, differential head wear can cause loss of contact between the head and the magnetic stripe. Stripes of varying thickness may reproduce poorly, if at all, and any considerable head grooving by narrow stripes running on full-width heads will eventually cause scratching of remaining photo-track areas.

Combination photo-magnetic tracks (for 16mm release prints) are thus hardly a solution to the interim problem, and we do not feel that supplying magnetic tracks to some TV stations and photographic tracks to others is at all practical.

Another consideration which should be investigated is the standardization of track advance for 16mm magnetic prints. The most obvious placement is making the magnetic track even up with the optical track. This places the magnetic pickup head at the sound drum, an unfortunate location in some projectors. The present 26-frame advance places severe mechanical restrictions on the design of projectors in that complete flutter isolation is usually hard to obtain. If more advance were used, better isolation could be obtained and easier threading of projectors and possibly a more optimum placement of the magnetic pickup head might result. While from mechanical considerations it might be worth while to increase the track advance, this poses another serious problem. It is common practice to leave 1½ seconds of silent film on TV commercials now so that they may be spliced head-to-tail with other spots without cutting off the track. The 36 frames of silent picture allow several splices to be made without coming too close to the track. If the track is advanced any further, more silent picture will have to be provided. The 1½ seconds already provided represent a considerable proportion of the so-called "10- and 20-second spots," and there probably would be considerable opposition to providing additional silent frames.

These problems, as well as other more minor considerations I have not mentioned, deserve very serious attention before additional magnetic-track standards are set up. It would be most unfortunate were we to go ahead using a medium which offers such considerably improved 16mm sound film quality in TV without first establishing procedures and standards which will permit it to be realized. Furthermore, in our opinion equally serious industry consideration should be given by all concerned to setting up an eventual definite date for complete changeover to the exclusive use of magnetic sound tracks in TV stations. It might be a very expensive operation, but in the long run we feel that it would be by far the safest plan.

GENERAL EDITORIAL COMMENT AND CURRENT STATUS REPORT

By R. T. Van Niman

Following the Washington convention, the Reeves Soundcraft Corp. paper on commercial striping experiences, the Bell & Howell Co. paper, the Minnesota Mining & Mfg. Co. paper, and the Eastman Kodak Co. paper were re-presented by their authors at the October 16, 1952, meeting of the SMPTE Central Section in Chicago. John K. Hilliard (Altec Lansing Corp., Hollywood), Chairman of the SMPTE Sound Committee, presided over the extensive discussion which followed. Much of this discussion duplicated that in Washington, and hence only non-duplicated items are summarized in these comments to conserve *Journal* space.

Since Mr. D'Arcy could not be present due to illness, Mr. Hilliard opened the discussion period by abstracting Mr. D'Arcy's Washington paper on magnetic standardization needs. He pointed out that the "sub-subcommittee" on Magnetic Reproduce Characteristics headed by Mr. D'Arcy has the exceedingly important job of reconciling present differences in such matters to the end that magnetic sound tracks recorded on one make of equipment eventually will reproduce satisfactorily on equipment furnished by other manufacturers. Such standardization appears possible without seriously limiting advancement of the art, and it is being strongly urged by both industrial equipment users

and by our Armed Forces, who plan extensive use of pre-recorded magnetic tracks. As is the case in all SMPTE activities involving the formulation of standards, participation in the work of the sub-subcommittee is open to all having a legitimate interest. Such persons and organizations not currently represented are requested to communicate with Mr. D'Arcy, or with Mr. Dimmick or Mr. Hilliard of the parent groups.

Dr. W. W. Wetzel of Minnesota Mining & Mfg. Co. answered questions from George Colburn (Geo. W. Colburn Laboratory) as to the reason for supplying the 3M laminating tape in quarter-inch width, with the excess beyond the desired track width being slit off after laminating. It is primarily to insure easier handling in the machine due to the greater tensile strength, and to permit the same machine to apply any of the track widths (100-mil, 50-mil, 32-mil) currently in use. The laminating cement is thermal-plastic and hence the slit-off portion of the tape can be re-used so long as it is 100 mils or more wide.

M. G. Townsley (Bell & Howell Co.) initiated a considerable discussion on head width versus magnetic-track width by expressing a feeling that the matter of differential wear caused by tracks narrower than heads is not nearly as serious as has been forecast in some quarters. True, it cannot be ignored, particularly in special cases where narrow tracks run always in the same position relative to a wider head. Even such cases may well be of little consequence in the future, however, due to the imminent advent of magnetic-head materials with enormously greater wear resistance than the present soft mu-metal.

Discussion between John Hilliard, Dr. Wetzel and others brought forth the information that heads narrower than tracks have the advantages of less amplitude modulation due to track width variations, they allow for some film weave at the scanning point, and they avoid possible head/track contact difficulties caused by having the head ride the extreme edges of the track, which frequently have ridges, varying slopes, or other discontinuities in the wet-coated types of tracks. Dr. Wetzel subsequently called attention, however, to the fact that laminated tracks have very flat, sharp edges, and track widths can be controlled with great accuracy. Assuming that highly wear-resistant head materials become available, a head wider than the widest track to be reproduced, in combination with laminated tracks, would have the extremely important advantage of being able to reproduce any width track with maximum output level and with complete freedom from the effects of film weave.

Current Status

As stated in Mr. D'Arcy's paper on standardization needs, the establishment of a standard reproduce frequency characteristic for 16mm magnetic sound tracks hinges upon the availability of magnetic frequency test films having known absolute values of magnetic induction at each frequency so as to permit separation of the reproduce characteristic from all other factors in the record-reproduce process. Actually, the job of reconciling existing differences in reproduce characteristics between machines of different manufacture could probably be accomplished reasonably well without test films of absolute calibration, provided all measurements were made with the same film (or with carefully recorded exact duplicate films). Much more confidence in the results, however, and better agreement as to their validity will obtain if independent means are available for determining the absolute values of magnetic induction.

Fortunately such means have very recently become available. In the months since the Washington convention sample frequency films have been produced by Edward P. Ancona, Jr., at RCA's New York film recording studio, and by C. C. Davis at the laboratories of Westrex Corp. in Hollywood. Both films were calibrated under Dr. J. G. Frayne's direction, using the short-gap method mentioned in the J. D. Bick (RCA Victor Div., Camden, N. J.) paper on methods for measuring surface induction which is published in this *Journal* issue. Earlier it had been found that the wide-gap calibration technique, which gave good results at 35mm film speed, was not at all satisfactory at the 16mm speed. After taking into account the somewhat more complex recording equalization used in producing the RCA film, the two films running in the same reproducer (with azimuth adjusted to suit the individual

film) gave relative outputs which were in good agreement, a point which helps to establish confidence in the suitability of the films for present purposes. In using magnetic frequency films, individual reproducer azimuth adjustments must necessarily be made until such time as the Society's standard azimuth films become available.

The Westrex film was made on a recorder equipped with facilities for producing an accurately aligned 100-mil sound record and the RCA film was produced under similar conditions with the exception of the sound record which is 200 mils wide. One of these films will be used as the standard frequency film for the Magnetic Reproduce Characteristics Sub-subcommittee's first project, the determination of present differences in reproduce characteristics of the various currently available 16mm magnetic projectors. Both films were forwarded to Chairman D'Arcy, who reports that his initial use indicates that they are entirely suitable for the purpose. Rather than circulating the original film, with attendant risk of loss or damage, it appears desirable to make identical copies, checking their individual calibrations against the original. At this writing (March 30, 1953) this work is under way. Every effort is being exerted toward having the secondary standard films in the hands of equipment manufacturers in time to allow reproduce characteristics to be measured and reported for consideration during the forthcoming SMPTE convention.

With satisfactory means for establishing in absolute terms the calibration of magnetic frequency films now available, it becomes possible to produce a single frequency standard signal-level magnetic test film, as discussed in Dr. Frayne's addendum to Mr. D'Arcy's paper on standardization needs. In a recent communication, Mr. D'Arcy points out that the need for such a film is great, and requests that those interested in it communicate with him by mail or during the Hollywood convention on the matter of setting up suitable specifications for its production. A standard signal-level magnetic test film is essential in all work leading to the establishment of standards for such reproducer characteristics as reserve gain, dynamic reproduction range, and permissible distortion. It is also essential for calibrating equipment to be used for the evaluation of different types of magnetic sound tracks with respect to optimum bias, coerciveness (sensitivity), and retentivity (aging). Standard signal-level films cannot be produced satisfactorily by employing only controlled recording conditions because of unavoidable variations in these track characteristics, and because it is extremely difficult to maintain over extended periods stable conditions with respect to such factors as head wear and intimacy of head/track contact. As Dr. Frayne states, having standard signal-level test films for field use individually calibrated in terms of the absolute value of magnetic induction may be neither necessary nor desirable. Mr. D'Arcy feels, however, that all primary standard signal-level and frequency films must be so calibrated if the standardization needs in magnetic recording and reproducing are to be met.